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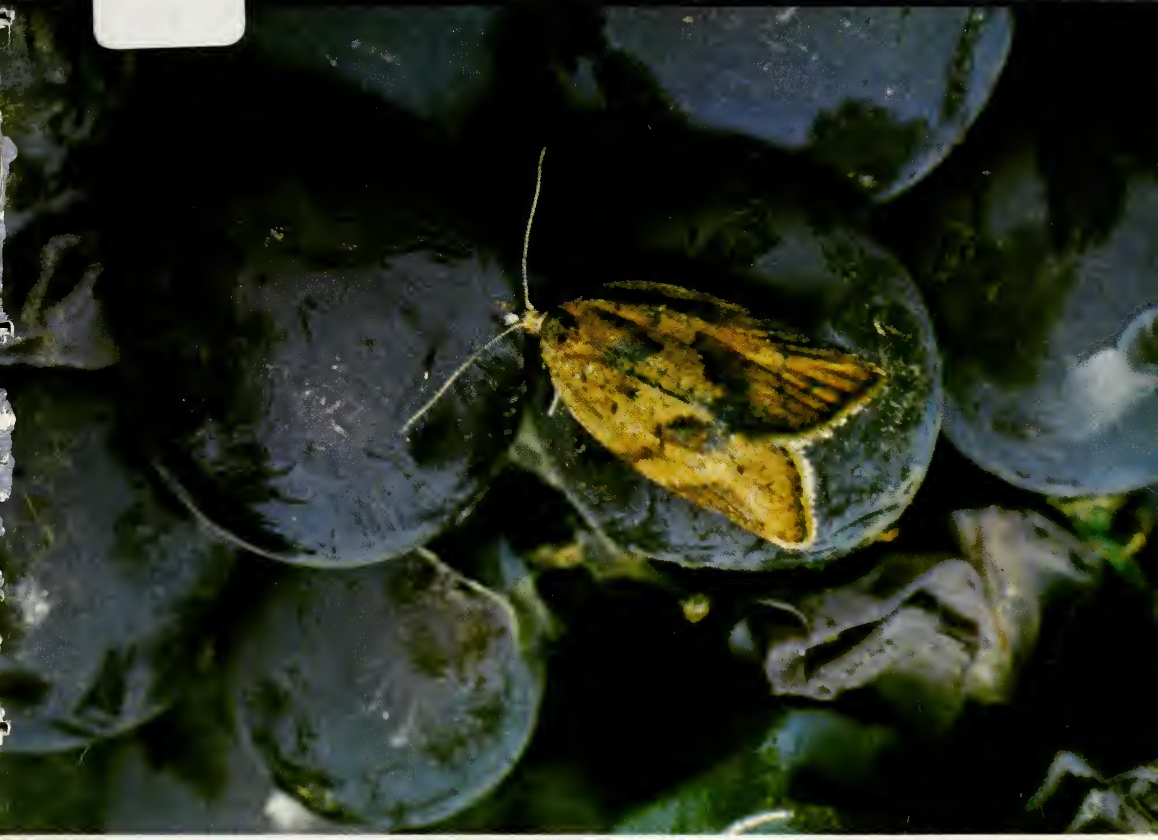

INSECT GRAPE PESTS OF NORTHERN CALIFORNIA

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THIS PUBLICATION

. . . identifies grape pests and the injuries they cause

. . . describes their life cycles, habits, and enemies

. . . defines the concept of integrated control and discusses the general principles of chemical control

. . . provides numerous photographs of the pests

Specific chemical control methods are not given because they change often and vary widely from one area to another. This circular replaces circular 445, "Grape Pests in California" by Leslie M. Smith and Eugene M. Stafford, and is largely based on material in that publication.

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PESTS THAT ATTACK . . .

The leaves

Grape leafhopper, 8; Pacific mite, 15; Willamette mite, 19; Omnivorous leaf roller, 20; grape leaf folder, 24; orange tortrix, 27; western grape skeletonizer, 29; grape erineum mite, 31; false chinch bug, 33; grape rust mite, 34; Sphinx moths, 35–36; grape whitefly, 36; insect vectors of Pierce's disease of grapevines, 37; grasshoppers, 38.

The flowers and fruit

Hoplia beetle, 40; consperse stink bug, 41; grape mealybug, 43; vinegar fly, 45; western flower thrips, 46; grape thrips, 47.

The canes, arms and trunk

Scale insects, 49; branch and twig borer, 50; termites, 51; cicadas, 53; darkling ground beetle, 54.

The buds and young shoots

Grape bug beetle, 54; cutworms, 56; click beetle, 57; little bear beetle, 58; flea beetle, 59.

The roots

Root-knot and other nematodes, 59–62; grape phylloxera, 62; western grape rootworm, 64; ground mealybug, 65.

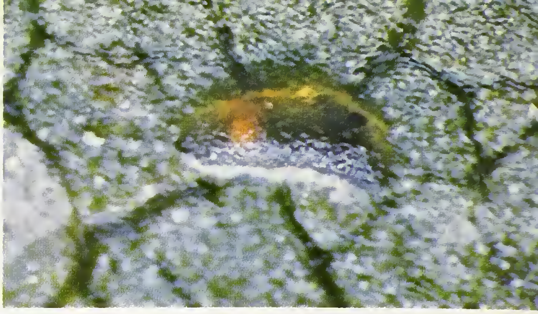
The raisins

Raisin moth, 66; Indian-meal moth, 67; dried-fruit beetle, 69; saw-toothed grain beetle, 70.

In wineries

Lead cable borer, 71; pomace fly, 72.

Grape leafhopper egg under epidermis of leaf. (Photo by F. E. Skinner.)



Grape leafhopper egg parasitized by *Anagrus epos*. (Photo by F. E. Skinner.)

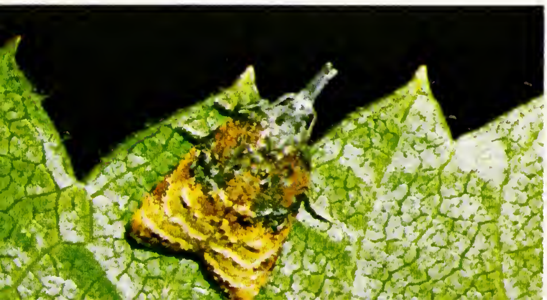
View of lower leaf surface showing damage caused by Pacific mites. Blue spots are spray deposits. (Photo by Visual Aids, UCD)

A colony of Pacific spider mites and an egg. (Photo by F. E. Skinner.)

Severe Pacific mite damage. (Photo by F. L. Jensen.)

Willamette mite damage along veins. Some leafhopper damage also present. (Photo by F. L. Jensen.)

Omnivorous leaf roller adult male. (Photo by Visual Aids, UCD.)



Grape leaf folder young stages, showing feeding damage to leaf. (Photo by F. L. Jensen.)

INSECT GRAPE PESTS OF NORTHERN CALIFORNIA

INTRODUCTION

A vineyard is a special ecosystem of complex interrelationships between plants, animals, cultural operations, and microclimates. Because of this complexity, an insect pest control program must harmoniously integrate desirable features of all control methods within a framework of practical vineyard operations. An integrated control program, therefore, is not merely a set of standard procedures. It is, rather, a program in which the grower seeks to combine the best of various techniques for control. When properly organized such a program offers maximum possibilities for efficient control, high yields of quality fruit, lowest economic costs, and minimum environmental disruption.

Natural mortality factors in integrated control

Every pest species is subjected to powerful natural forces which cause mortality and often maintain satisfactory control of the species. While these forces may vary from place to place and throughout a season they can be greatly assisted by certain cultural practices. Thus the field evaluation of such forces is an important primary ingredient in integrated control of pests. This makes an integrated program more complex than methods used in the past, but signs of natural mortality in the field can be quickly learned and benefits derived from using this approach amply repay the effort it requires.

The important natural forces causing mortality of vineyards pests are their parasites, predators, and diseases (biological control). Fortunately, these natural enemies are subject to human manipulation and their maximum effectiveness can be regularly encouraged through certain cultural practices. Among these are general vineyard sanitation, judicious cultivation, grass culture, and (in some situations) sprinkler irrigation.

The economic threshold

Damage from pests is a function of their numbers or more correctly of their population density, which is often expressed in such terms as the "average number of leafhopper nymphs per leaf" or "the number of leaf rolls for the area of a vine." Biological control requires a minimal population level of the pest to maintain the presence of its predaceous and parasitic enemies, but this minimum level should be below the "economic threshold"—the point at which pest abundance clearly threatens to cause economic damage in excess of the cost of control treatment.

Economic thresholds are difficult to determine with precision. In certain cases, however, we know that low populations do not require treatment and the limited research data available permit us to set useful economic levels. An example is the setting of 10 nymphs per leaf in the first leafhopper brood on Thompson Seedless vines grown for raisins or wine. Growers who have used this guideline in the San Joaquin Valley have repeatedly been able to withhold treatments without any detectable loss of quality or yield.

Manipulating and encouraging natural enemies is much less expensive than using insecticides. It is now recognized that there are costs of treatment in excess of the grape grower's direct cost for material, labor of application, and spray equipment. For example, additional costs

arise from disruption to the immediate ecosystem by insecticides (with much broader effects reported for some chlorinated hydrocarbon insecticides). There are social costs in potential health hazards to applicators and farm workers, or other persons who may be affected by residues or over-exposure to empty containers. And there are indirect costs for supporting public agencies which provide necessary regulatory or research functions in connection with pesticides. It is, therefore, difficult to determine the true economic threshold for a pest, so the properly integrated program requires that pesticides be used only when necessary and then vary carefully in compliance with current recommendations and regulations. Grape growers should also remember that these applications may be justified in only a portion of a vineyard, and that such spot treatments will, unlike blanket treatments, tend to minimize ecological disturbances.

It often takes several years to devise a program in which chemical control is harmonized with non-chemical methods. While natural balances are being established during that time, judicious selection and use of chemicals are necessary. Insecticides for use against occasionally harmful pests are valuable to a control program which relies heavily on natural enemies of the pest—this is because insecticides are immediate in their action and the cost-benefit ratio is generally favorable.

An integrated program must be adjusted to specific situations—vineyard locations can, for example, have an influence on the occurrence of damaging levels of certain insect and mite pests of grapes. Furthermore, different grape varieties react differently to different pests. In addition to intrinisic differences in susceptibilities to insects, the grape variety is often related to a particular use or market such as table, wine or raisin grapes, and varieties are grown under different cultural practices depending on their intended use. All of these factors interact and must be weighed in the process of making decisions on treatment. Economic levels, therefore, vary with the variety, location, size of farm operation, and end-use of the crop. Generally, such levels are somewhat lower for table grapes than for grapes destined for wine or raisins.

Integrated control is most effective when tailored to a particular vineyard situation. It is of the greatest importance that a grower should know the pest population level in his own vineyard and the conditions that make chemical control necessary. In adopting an integrated control program, the grower may initially wish to seek expert advice, but he should soon be able to rely on his own seasoned experience and judgment.

Although more than 30 types of pests attack grapes in northern California, only the following are considered as frequently serious: grape leafhopper, Pacific spider mite, phylloxera, grape leaf folder, omnivorous leaf roller, cutworms, and grape mealybug. Of somewhat less general importance are grape bud beetle, grasshoppers, thrips, hoplia beetle, and Willamette mite. Usually very few of the serious pests are of economic importance in any one vineyard in a given year. Often natural enemies and climatic factors are not numerous enough to hold pests to tolerable levels so insecticides must be used. Physical and biological factors govern the spotty distribution of grape pests but natural enemies of the pests are, to the greatest extent, responsible for variations in pest abundance. Without their aid grape growing would be almost impossible.

Chemical control

The grape grower should work toward a situation in which vineyard practices permit natural enemies, rather than chemicals, to play the major role in preventing pests from reaching economic levels.

When chemical control becomes necessary, however, certain general considerations should be borne in mind. First, the insect or mite that is causing the damage should be correctly identified and the best chemical for the problem should be selected. If appearance of the berries is important, it should be remembered that residues from wettable powder are likely to be more pronounced than are residues from emulsifiable concentrates. Emulsifiable concentrates, however, are more likely to cause fruit spotting than will wettable powders. Berries may be more marked by dilute than by concentrated sprays. Spraying at short intervals or with combinations of insecticides may cause injury to leaves and berries in some cases, and certain pesticide chemicals when mixed may react to form a new chemical injurious to plants. Some spray chemicals are not "compatible" when mixed in the spray tank and use of such a mixture may cause injury to vines. Growers should carefully check to be sure that the chemicals are compatible.

For control of some pests, good coverage of vines when applying insecticides may be as important as using correct insecticides. Application machinery must be adjusted properly and driven through the vineyard at a speed low enough to obtain good coverage. Driving through every "middle" instead of every other middle increases coverage.

Berries and leaves of some grape varieties are more susceptible to insecticide injury than others, especially in spring. Environmental conditions affect susceptibility of pests to chemical control as well as susceptibility of vines to insecticide injury. Usually, these susceptibilities increase with increasing temperature. Vine growth produced at cool temperatures (maximum daily temperatures of 80°F or less) tends to be susceptible to injury by heat, sulfur dust, or oil spray, especially if the weather suddenly turns warm after an extended cool period. Mature leaves toughened by warm weather are often much more resistant to chemical injury.

Finally, the grape grower must be sure to meet all legal requirements for safety to man including permits for use of injurious and restricted chemicals, timing of application and amounts per acre limitations, notices to nearby beekeepers of intent to apply insecticides, posting of treated property when necessary, and use of only those chemicals registered for use on grapes. Other considerations in using chemicals will be discussed under the specific pests.

Resistance to pesticides

The necessity for integrated control has been emphasized by the increasing occurrence of resistance of insects and spider mites to insecticides and acaricides. Generally, an insect population that has become resistant to an insecticide by many generations of partially-killing exposure to the insecticide (selective pressure) will also show resistance to a closely related insecticide—this is called "cross-resistance." Insects develop high degrees of resistance to chlorinated hydrocarbon insecticides (DDT, lindane, dieldrin, etc.) and resistance is relatively stable when exposure to the insecticide is removed. Resistance to a selective organophosphorus insecticide does not develop to nearly as high a degree, nor is the resistance as stable. This generalization may, however, vary greatly in degree for a particular insect and insecticide. For example, after the grape leafhopper became resistant to DDT, it quickly became resistant to other chlorinated hydrocarbon insecticides with the exception of Thiodan® (endosulfan) which effectively controlled grape leafhoppers for many years. A four-fold increase in cost of chemical control due to increased resistance can be serious. Populations of insects often develop a resistance of ten-fold or greater when subjected to frequent ex-

posures to an insecticide. In some cases insects have been suppressed by insecticides for many years by means of shifting to alternate insecticides as resistance developed to the original pesticides. After resistance to one insecticide occurs, combinations of insecticides are often used to combat resistance even though this increases cost and may be more hazardous to vines, the applicator, and to beneficial insects.

There have been no confirmed reports of resistance to spray oil.

Good management is needed for achieving integrated control because each vineyard may present different control problems. Considering the many possible problems in the use of chemical control—plant injury, coverage, weather, legal requirements, resistance, etc.—the grower should consider the possible short- and long-term detrimental effects in deciding what to do to correct an immediate or impending pest problem.

Other biological agents are being studied and some of these may eventually be used as controls for certain insect pests. These agents include bacteria, nematodes, fungi, and viruses that are specific for insects or certain groups of insects. Resistant grape varieties would, however, afford best control.

GRAPE LEAFHOPPER

Almost every grape grower in the interior regions of northern Califorina recognizes the typical light-colored mottling of the leaves that results from the feeding of the grape leafhopper, *Erythroneura elegantula* Osb. The grape leafhopper occurs in every major grape-growing area in northern California. A closely related species, the variegated leafhopper, *Erythroneura variabilis* Bea., damages grapes in southern California but is not found north of the Tehachapi Mountains. Several periodic attacks in 1907–1908, 1913–1914, and 1929–1932 of the grape leafhopper have caused great damage, particularly in the southern San Joaquin Valley.

Adverse weather conditions have been credited with sudden decreases in leafhopper populations. Two to three weeks of heavy rains have been reported to decimate overwintering leafhoppers because of subsequent fungus growth. The grape leafhopper is also attacked by predators and parasitic wasps.

Adult grape leafhopper. (Photo by Lorry Dunning.)

Appearance. Adult leafhoppers are narrow insects a little less than ⅛-inch long, and are pale yellow with reddish and dark-brown markings forming a characteristic pattern. On overwintering adults the markings are a darker red than are those of spring and summer broods. There are distinct dark-brown spots on wings and scutellum. Newly-emerged adults have pale markings which darken with age.

Development. The grape leafhopper overwinters as unmated adults. As soon as leaves drop from the vines, the adult leafhoppers migrate to other plants to feed. They are often found on filaree, clover, alfalfa, dock, wild mustard, grasses, orange trees (where they contribute to

a typical rind scarring), and other green plants. During colder weather leafhoppers may be found in large numbers in the shelter of leaves or rubbish in vineyards or along bordering roadsides and fences. They also seek shelter on low-growing weeds, especially filaree. Cold wet weather in the dormant season reduces the numbers of overwintering adults. The leafhoppers show little activity at 60° to 65°F but revive at about 70°F. The overwintering adults have been found as far as 1 mile from the nearest grapes, but most of them spend the winter much nearer or actually in the vineyards.

As soon as the vines leaf out in the spring the overwintered adults begin to move into the vineyards and feed on the developing leaves. If present in large numbers the overwintered leafhoppers may cause considerable damage. On cool nights they go to cover crops or other shelter on the ground and return to the vines the next day when it becomes warmer. Mating occurs on the vines or on weeds. The basal grape leaves are attacked first. About 2 weeks after moving to the vines they begin to lay eggs, and each female lays from 75 to 100 eggs over a period of 1 or 2 months. A single male has been observed to mate with two virgin females with resulting viable eggs in each case. The eggs are about $^{3}/_{100}$-inch long and are inserted singly into the leaf tissue just beneath the surface, causing a bean-shaped blister. They are difficult to see even with a hand lens. Eggs are laid on both leaf surfaces in no particular pattern except that they are found more frequently near the edge of the leaf. The small spherical outgrowths from the veins of the lower surface of young leaves should not be mistaken for eggs of the leafhopper or grape leaf folder, or for any other insect.

The eggs of the first brood hatch in 18 to 20 days depending on the temperature. The young leafhopper (nymph) emerges through a slit in the egg, and if the egg was laid in the upper surface of the leaf the nymph soon goes to the underside. Most of the nymphs, large or small, are found on the lower leaf surface. The first nymphal stage seems almost transparent and colorless except for the prominent red eyes. After feeding a while, the nymph molts to become a second-stage nymph. This process is repeated five times before the leafhopper becomes an adult. About 18 days are passed in the five nymphal stages of the first brood. Each stage looks like the preceding one except that it is larger and the rudimentary wings are longer. When disturbed the nymphs often run with a sideways, crab-like movement. The later nymphal stages are very light green. Since the nymphs tend to stay on the leaves where they hatch out, heavily-infested leaves will show many whitish shriveled cast-skins.

Mating takes place about 2 weeks after the adult stage is reached, and egg-laying begins about 1 week later. The second brood of eggs takes only 8 to 12 days to hatch. A complete cycle in mid-summer takes 3 to 4 weeks. Eggs are laid in the

Grape leafhopper nymph hatching from egg. (Photo by F. E. Skinner.)

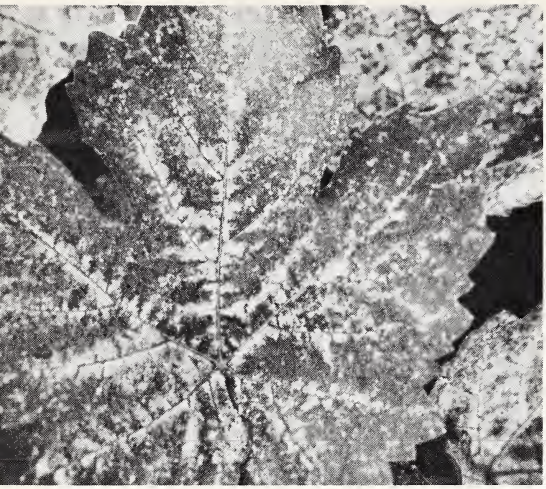
Grape leafhopper nymphs. (Photo by F. E. Skinner.)

leaves of the Virginia creeper vine, but not in weeds or cover crops in the vineyard. Where the season is long enough, there is a third generation each year. Eggs of the third generation are laid beginning July 20 to 30, and the peak of oviposition follows in about 2 weeks in the Fresno area. There is no third generation in the Lodi area and the nymphs are not found after about October 15. The date for disappearance of nymphs in the Fresno area is about October 20.

In Fresno and Tulare Counties, the first eggs may appear from early April to early May depending on the weather. The first hatching may extend from April 4 to May 20, and the first summer adults appear from May 20 to 25. Comparable dates for the second brood of leafhoppers are: first eggs, June 5 to 10; first hatching, June 25 to 30; and first appearance of second brood adults, July 1 to 8. For the third brood the dates are: July 25 to 30, August 10 to 15, and August 25 to 30. In the Lodi area the dates would be from 10 to 14 days later except that there is no third brood. Occasionally, the grape leafhopper is an economic pest in the Napa and Sonoma valleys but they are usually kept in check by natural enemies, especially the egg parasite.

Overwintered adults move into vineyards and scatter fairly evenly as the uniform occurrence of nymphs in vineyards in May demonstrates. However, more leafhoppers are generally found on end vines and borders adjoining good overwintering food sources and shelter. Numbers and stages of nymphs on leaves at different locations on the cane vary throughout the season. In spring most of the nymphs are found on the basal leaves and are mostly in the same developmental stages on any one date. Later the population moves toward the distal portion of the cane, giving a more uniform distribution; at this time there is a greater mixture of nymphal stages on the leaves. The more immature forms are found on the more distal portion of the cane. Adults appear to prefer newly-matured leaves for oviposition. Adults do not tend to move very far as long as there are optimum conditions for reproduction. Movement in the summer appears to be away from early-harvested vineyards low in soil moisture to vineyards where the fruit is not mature and where vines are watered more frequently.

Sometimes leafhoppers are so numerous at harvest as to be a nuisance to the pickers. Swarms of leafhoppers may emerge from the vines when they are disturbed, flying into the eyes and nostrils of the pickers. In attempts to feed on the



View of upper leaf surface showing damage caused by leafhopper nymphs feeding on lower surface of leaf. (Photo by F. L. Jensen.)

Grape leafhopper damage on lower leaf surface. Note black spots of excreta and cast skins of nymphs. (Photo by Visual Aids, UCD.)

exposed skin of the pickers many leafhoppers will insert their mouthparts and cause additional discomfort.

Leaf injury. While the vines are in leaf the leafhoppers feed on them to the exclusion of all unrelated plants.

Both nymphs and adults feed by sticking their mouthparts into the leaves and sucking out the contents. Much of this ingested liquid material is excreted in small drops. In July when temperatures are high there is a morning and an afternoon peak in the rate of feeding (measured by the number of droppings per insect). This gradually changes to a single feeding peak in September as daily temperatures decrease. In general, rate of feeding increases with temperature to about 85° to 90°F and decreases at higher temperatures. Most feeding takes place in daylight. The removal of green chlorophyll results in a pale spot around the point where the leafhopper has punctured the leaf. As the feeding punctures become more numerous, the pale areas grow larger and the leaf becomes characteristically mottled or variegated. The whole leaf may turn pale, die, turn brown, and then fall. The older leaves in the crown of the vine are attacked first. If many leaves are so badly injured that they fall, the bunches may be sunburned. Lesser damages may cause deformed leaves, development of low sugar content in the berries, poorly-maturing canes in the fall, and consequent weak growth of vines the following spring.

At first, the nymphs from the eggs laid by overwintered leafhoppers do most of their feeding along the main veins of the lower surface of the leaves, while feeding by large nymphs and adults is more scattered. Thus in May or June the damage as seen on the upper surfaces may have the appearance of feeding by Willamette or Pacific spider mites. However, the lower surfaces of the leaves infested with grape leafhoppers will show nymphs, cast skins, and dark excrement droppings, especially where adult leafhoppers have fed.

The sticky drops of leafhopper excrement catch dust particles and also support growth of a black fungus; such excreta on table grapes detract from their appearance and lower their value. California standards for table grapes have no

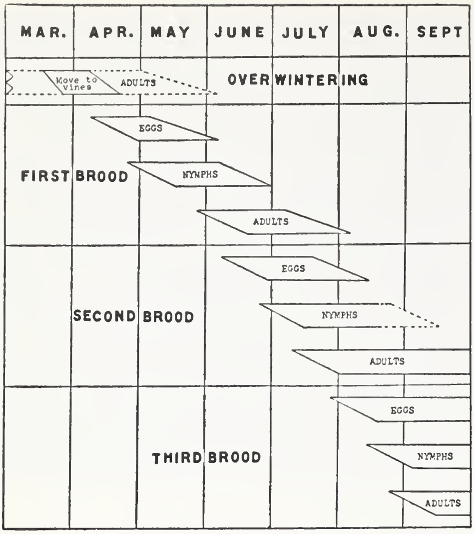


Diagram representing life history of the grape leafhopper in relation to time of appearance and length of various stages of its broods. Note that as season advances the overlapping of broods becomes more complex. (After Lamimam.)

tolerance limits for number of excrement spots per unit of berry surface. In an attempt to correlate numbers of leafhopper nymphs with appearance of table grapes, 75 and 100 spots per square centimeter were set as causing excessive spotting for white and colored table grapes, respectively. Counts of spots were made from the berries on upper shoulders of the bunches. Because spotting of berries is cumulative through the growing season, counts of leafhopper nymphs at intervals were converted to the number of "nymphal-days" (average number of nymphs per leaf times number of days between nymph-count observations) accumulated over the counting periods. Trials indicated an "excessive spotting" at 250 nymphal days. The relationship between nymphal-days and excessive spotting is not constant because nymphal counts are only estimates of the number of future adults (the stage that causes most of the spotting). Also, spots are subject to re-

Italia grapes, showing drops of leafhopper excrement blackened by sooty fungus. (Photo by F. E. Skinner.)

duction by weathering, especially by rain. Populations of leafhoppers just large enough to cause excessive spotting are not large enough to reduce yields or quality of the fruit, or to damage the vine.

Thompson Seedless grapes to be used for wine or raisin production only can tolerate 20 nymphs per leaf in the first generation and 10 nymphs per leaf in the second generation in the San Joaquin Valley. On very young vines and on less vigorous vines in other grape-growing areas of California, such infestations may do considerable damage.

Control: biological. Among the enemies of the grape leafhopper the parasite *Anagrus epos* Girault is particularly effective because it has the ability to find most of the host eggs. Under suitable conditions few eggs remain unparasitized after the middle of the summer. This is accomplished because the parasite appears early in the season, disperses rapidly, and completes about three generations to one of the leafhopper. The parasitized eggs turn red and are less difficult to see than normal leafhopper eggs, and presence is an indication of *Anagrus* activity. The adult parasite is only a few hundredths of an inch long and very difficult to see.

In winter, there are no grape leaves and no grape leafhopper eggs.

The *Anagrus* breeds throughout the year on eggs of a non-economic native leafhopper, *Dikrella cruentata* Gillette, on wild blackberries which retain their leaves in winter. In spring, a great increase in *Anagrus* on wild blackberries tends to coincide with the first egg-laying of overwintered grape leafhoppers. Vineyards near blackberries tend to receive most benefit from *Anagrus* each summer. Attempts have been made to establish blackberry and *Dikrella* refuges near vineyards at considerable distances from any wild blackberries. For this purpose, blackberry varieties that retain their leaves in winter are used. The best varieties are Cory thornless, Ollalie, and Chehalem. A mixture of Himalaya and selections of the native *Rubus ursinus* has been satisfactory. The value of these refuges has varied but a well-managed refuge is an asset. In some cases refuges have provided earlier establishment of *Anagrus* in spring, with consequent increase in effectiveness of biological control. (Refuges should have at least partial shade to be most effective.) Some minor disadvantages of blackberry refuges are: they may also be refuges for overwintering grape leafhoppers, they attract birds, require space, care, and especially, irrigation.

Control: chemical. Depending on how serious the problem is, control might begin early in the season before the vines leaf out. Control would be directed against overwintered leafhoppers found on weeds in the vineyards or on borders of the vineyard, on weedy ditch banks, in adjoining alfalfa fields, or on other leafy plants providing shelter and food. Treatment of alfalfa fields and other crops must be done without leaving harmful residues. Plowing weeds or trap crops in the vineyards when the temperature is below 55°F kills many adult leafhoppers. Chemical treatments at this time would not harm egg parasites because they have not yet migrated back to the vineyard from their overwintering habitats. In choosing an insecticide one must consider that most insecticides work slowly at low temperatures—so an insecticide of good contact and systemic action should be chosen. If overwintered adults appear in large enough numbers to require chemical control after the vines leaf out, treatment of vines should not be made at temperatures below 70°F because the leafhoppers may be in sheltered places on the ground where they may not be contacted by the spray. Such low temperatures may be encountered in early mornings at the beginning and end of summer. Summer

broods are more affected by cold than are overwintering leafhoppers. In case of a control failure one should always consider the possibility that leafhoppers may have become resistant to insecticides, especially where the same chemical has been used regularly for several years.

In treating plants that shelter overwintering adults, care must be taken not to leave above-tolerance residues on food or forage crops. Where vines grow vigorously there is seldom any need for control of overwintered adults even though damage from their feeding on older leaves may easily be seen. Growth of such vines continues (especially in the San Joaquin Valley) despite the presence of numerous overwintered leafhoppers.

Chemical control of first brood on vines is not recommended because of adverse effects on the egg parasite and other natural enemies of the grape leafhopper, and on other grape insect and spider mite pests. Even though some leaf damage may result from the first brood, control by the egg parasite often reduces the second brood to the level of no economic damage and holds this level for the remainder of the season. Of course, economic levels differ according to the use of the grapes. Vineyards of late-season table grapes are more likely to require chemical control than vineyards whose crops are intended for wine or raisins. If past experience or some other reason indicates the need for chemical treatment of the first brood, then the preferred time for application is when all eggs of overwintered adults have hatched and before, or just as, the first adults of the first brood begin to appear. This occurs in late May or early June in the Fresno area, depending on the weather.

The decision to use chemical control and what chemical to use is an important one because spider mites, especially the Pacific mite, can be much more injurious than leafhoppers. The use of chemicals may upset the biological control of the Pacific mite and lead to a situation where even greater use of chemicals will be needed. As mentioned previously, Thompson Seedless grapes for wine or raisin production can tolerate only 20 nymphs per leaf in the first generation and 10 nymphs per leaf in the second generation.

Growers should consult their local Farm Advisor for current chemical control recommendations.

For determining the degree of infestation the following method of surveying leafhopper populations has been used in vineyards in the southern San Joaquin Valley. The method does not consider the adults (which is a disadvantage) but it does give a useful measure of the relative number of nymphs. (1) Walk along opposite ends of the vineyard or block of vines. At every fifth row, go into the third vine and select one leaf for examination. Avoid the outside rows and the two end vines, since these usually show higher-than-normal populations. (2) In surveying the first brood population, select one of the basal leaves on the cane. The second through sixth leaves give highest counts. In surveying the second brood, select mid-cane leaves. (3) Look for evidence of feeding damage as a guide in selecting leaves for nymphal counts. Before beginning the counts on any particular day, examine a few leaves at different locations on the cane to determine which ones are likely to give highest counts. Sometimes in August more nymphs will be found on basal leaves than farther out on the canes. The aim of the method is to pick the most heavily infested leaves. However, once the counts are begun, never discard any leaf that has been selected even if no nymphs are found. (4) Two or three counts for the first brood and additional counts every 10 days or 2 weeks beginning with the second brood, are sufficient. Should pop-

ulations appear to be changing rapidly, additional counts may be necessary. Increasing populations are always reflected in counts of nymphs which are few at first. The young nymphs do little damage, so a few days delay in counting or treating does little harm. (5) For any block, count a minimum of 15 leaves. Total the number of nymphs and divide by the number of leaves examined to obtain the average number of nymphs per leaf. Keep figures separate for each block.

This method is used in vineyards ranging from 10 to 40 acres in size and takes 2 or 3 minutes per acre. On larger commercial acreages, a slightly different system has been used successfully. Because it is faster to drive than walk between sample locations, three leaves were examined at every thirtieth row at each end of the block rather than one leaf every fifth row. Using this system, an average of only one leaf rather than two was examined per acre. No block less than 20 acres in size is suitable for this method.

To permit reduced use of insecticides, biological control must be more effective on table grapes than on wine or raisin grapes (where appearance is much less important). Unfortunately, the most effective enemy, the *Anagrus* parasite of the grape leafhopper eggs, is not present in large enough numbers in most areas where table grapes are grown. Also, in these same areas the leafhoppers have become resistant to insecticides so that combinations of chemicals and more numerous applications must be used. Two important factors for biological control appear to be successful management of blackberry refuges and the use of selective insecticides.

If leafhoppers are so numerous as to interfere with harvesting, they should be controlled with chemicals and timings of application that will not be hazardous to pickers or leave objectionable residues on the grapes.

PACIFIC MITE

Adult male Pacific mite. (Photo by Lorry Dunning.)

Two kinds of red spider mites—the Pacific mite and the Willamette—do serious damage to vines in California. By far the more destructive of the two is the Pacific mite, *Tetranychus pacificus* McG. However, it is very difficult to distinguish between these two pests because they are just barely visible to the unaided eye even when fully grown. Positive identification depends on microscopic anatomical differences, and is best accomplished by a specialist.

Appearance. Under a magnifying glass of at least 10-power the Pacific mite on grapes is usually pale amber to reddish with two, four, or six large black spots on its back. The Willamette mite is usually

pale yellow with a row of minute inconspicuous black dots along each side of the body. Adult Pacific mites are larger and produce more webbing than do Willamette mites. Pacific mites prefer the sunnier and therefore upper parts of the vine, particularly shoots that grow straight up from the tops of vines.

Development. In winter, Pacific mites hibernate under the bark of the trunk and arms of the vine. Their body color becomes orange and no trace of the black spots remains. The mites often squeeze their bodies into such small spaces that they lose their typical oval form and become misshapened to fit the crevices. They prefer the ripples in the bark where an arm joins the trunk. Growers may strip the bark from such places during the winter and look for the bright orange bodies. Unless the mites are hibernating in large numbers, they may be difficult to see. Failure to find the mites in the winter does not indicate that the vineyard will be free from mite damage the following season, since a few individuals too sparse to be noticed may give rise to a damaging population. Only adult females hibernate.

With warm spring weather the females move from the bark to the opening buds at about the time the first leaf opens from the bud. The mites begin to feed on the lower surfaces of the young leaves immediately, and the orange color is soon lost. After a day or two the dark spots appear. Small groups of mites may feed together, forming incipient colonies. Egg laying begins within a few days of emergence from hibernating sites.

Development from egg to adult is slow during cool spring days, and it may require a month or even 6 weeks to complete a generation. Later in the spring, under the influence of increasing temperatures, the rate of growth and egg laying is speeded up. The egg hatches in 1½ to 3 days into a larva which has six legs. The larva molts and becomes another immature form, the protonymph, which has eight legs. The protonymph molts to form the last immature stage, the deutonymph, which also has eight legs. Each of these immature stages takes 2 to 4 days to complete, depending on the temperature. The first half of each period is a feeding stage; the second half is a resting stage preceding the molt to the next advanced stage. After molting, the deutonymph becomes a male or female adult. A generation may be completed in less than 10 days in hot weather in the San Joaquin Valley, though it usually takes from 10 to 15 days. Mature adults live about 30 days, and females may lay as many as five eggs a day.

If vines have been severly defoliated, the first mites enter hibernation in June. From July through September more and more mites go into hibernation under the bark, this movement is probably the result of reduced food supply caused by severe mite injury to the vine. In some areas there is a decrease in Pacific mite populations and injury starting in about mid-August, but this does not appear to be due to lack of food or the presence of abundant predators. In general, as days become shorter and cooler in autumn the reproduction rate of the mite slows and fewer and fewer Pacific mites are found on the leaves.

Injury. The first appearance of Pacific spider mites generally occurs in spots in the vineyard, usually in the same areas year after year. All areas of "weak vines" are favorite habitats for this mite. The first signs of Pacific mite injury are yellow spots on the upper leaf surface. These are usually somewhat smaller than a dime when first noticed and may begin to appear in April and May. In the Fresno area from May to early June, the vines grow very rapidly so that increase of Pacific mites per leaf is not very great and increase in mite damage is minimal.

With the advent of warm days in June, mites increase more rapidly and damage

View of upper leaf surface showing damage caused by Pacific mites feeding on the leaf's lower surface. (Photo by Visual Aids, UCD.)

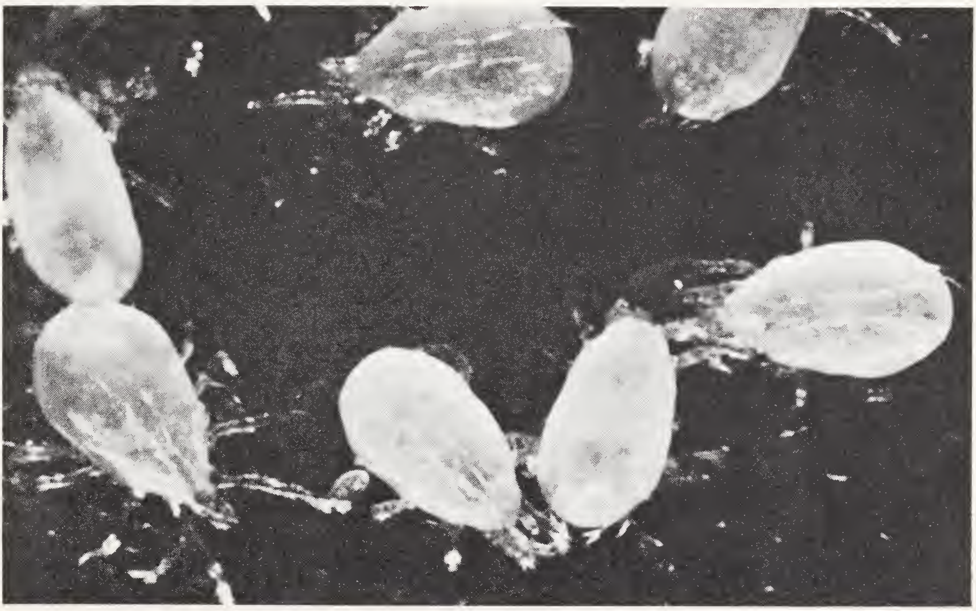
spreads quickly from a yellow spot to along the main veins and then to the entire leaf. Mites then crawl along the cane to adjacent leaves. Thus at one stage of development of injury it is usual to find one or more severely injured parts of the vine while the remainder is green.

Hot weather causes a rapid development of mite damage that often catches the grower napping. Ten days may suffice for a green healthy vineyard to change to a sickly brown, with vines severely injured.

On white grape varieties such as Thompson Seedless, the yellowed leaves turn light-brown as injury advances and finally the dead brown areas dry out. On black varieties, such as Zinfandel, yellow areas soon turn red, then purplish-red, and leaf tissue dies; as the dead leaf tissue dries out, it turns brown. Experienced growers can distinguish the dark, purplish-red color caused by the Pacific mite from the pinkish-red color produced by the grape leafhopper.

Control: biological. In the absence of natural or artificial checks, the Pacific mite builds up so rapidly (especially in hot weather) and has such a potential for damage that the population must be watched closely. If Pacific mite is present in a San Joaquin Valley vineyard having no natural enemies, chemical control will almost always be needed.

Predaceous mites, *Metaseiulus* species. (Photo by K. Middleham.)



The most important biological control agent for the Pacific mite is the predaceous mite *Metaseiulus occidentalis* (Nesbitt), which is about the same size as the Pacific mite but more oval in shape. It is pale, translucent, pearl-white, and without dark spots, and feeds on all stages of Pacific and Willamette mites. Effectiveness of the predaceous mite depends on its time of appearance in the vineyard, numbers, and distribution, in relation to time of appearance, numbers, and distribution of the Pacific mite. Even if predaceous mites are outnumbered, they can bring large populations of Pacific mites under control if the Pacific mites do not get too much of a head-start. Use of nonselective insecticides or acaricides and, particularly, combinations of chemicals may prevent predaceous mites from suppressing Pacific mites. This may come about because the chemical used kills relatively more predaceous than Pacific mites. It is reported that certain chemicals have a stimulating effect on Pacific mite reproduction. Regardless of how it is brought about, once an imbalance (low predator-to-prey ratios and poor distribution of predators on the vines relative to that of the prey) has occurred, an explosive increase may occur that can only be controlled by repeated applications of acaricides.

Other, less effective bio-control agents are six-spotted thrips, ladybird beetles, minute pirate bugs, and lacewings. Six-spotted thrips are important predators, especially in late season.

Changes in environment and in cultural practices also influence the abundance of spider mites. Dust on leaves encourages the Pacific spider mite, but can be reduced by oiling roads and planting cover crops in the vineyards—the type of cover crop used will depend on the use of the friut (i.e. for table grapes, wine, or raisins). Some cover crops need mowing for frost protection in late March or April, depending on the area, but others grow so low that mowing is not needed. For drying raisins in the vineyards it is necessary to disk the cover crop under by mid-July to properly prepare the soil for paper trays. By providing refuges and alternate hosts for predaceous mites cover crops may reduce the rate of build-up of the Pacific mite and may thus reduce the number of treatments required. Damaging numbers of Pacific mites often appear first in spots of weak vines, and if the cause of the weak vines can be corrected the early build-up on them may be reduced.

Increased numbers of predaceous mites depend on the presence of prey. Populations of Pacific mites in spring often are not large enough to build up the predaceous mites rapidly. If an alternate prey is present in enough numbers, predaceous mites can build up more rapidly. The Willamette mite, *Eotetranychus willametti* (*Ewing*), and the two-spotted mite, *Tetranychus urticae* Koch, are alternate preys. Fortunately, in the southern San Joaquin Valley these latter seldom do much damage because they lack potential to reproduce as rapidly as Pacific mites during hot, mid-season weather. In this area, therefore, unless considerable damage is expected (because of the past history of the vineyard) it is better not to control the Willamette or the two-spotted mite—it is best to leave them as prey to help build up predaceous mites. Another reason for not applying an acaricide is that it will reduce the number of tydeid mites that may be present and which also serve as alternate prey for predaceous mites. (The tydeids live on wind-disseminated pollen and are not injurious to grapevines.) Other conditions, such as minimal amounts of road dust and high humidity, favor the buildup of predaceous mites or slow increase in the Pacific mite. These conditions can be encouraged by oiling roadways and using summer-grass culture when possible.

Overhead irrigation sprinklers can be used to control Pacific spider mites, apparently by a washing and drowning ef-

fect. Fortunately, the predaceous mite is not reduced in numbers by this type of irrigaton. More frequent sprinkling than usual may be necessary, but sprinkling must be stopped by the end of July to prevent berry cracking of Thompson Seedless grapes.

Control: chemical. Regardless of the origin of any predatory mite-Pacific mite imbalance, there are vineyards where chemical control is necessary. With close supervision and a knowledge of factors affecting build-up and efficiency of predatory mites, growers may effect a trend toward fewer applications of acaricides or towards complete reliance on control by predatory mites. Each vineyard must be watched closely and judged for Pacific mite economic injury potential once a week in cool weather and two or three times per week as temperatures rise. Factors involved in these judgements include the extent of Pacific mite infestation and the numbers and distribution of the predatory mites. (The presence of other natural enemies may also be a factor.) Every opportunity must be given the predatory mite to build up to the point where it begins to suppress the Pacific mite—this means that chemical control should be delayed as long as possible. Vigorous vines on good soil (not alkaline and compacted, and not infested with nematodes or phylloxera) with good moisture supply and free from excessive road dust can withstand larger populations of Pacific mites. On such vines chemical treatments can be delayed for a few days, thus giving predaceous mites more time to increase.

If chemical treatment is obviously needed, use an acaricide that will permit survival of a sufficient number of predaceous mites to become useful control agents in the future. Such a procedure (the use of a selective acaricide) requires a delicate balance, and may result in some economic damage by the Pacific mites. Because predaceous mites have become resistant to certain acaricides in other crops in other areas, they may become resistant to acaricides now used in vineyards. The development of such resistance may become a significant factor in efforts to increase the effectiveness of predaceous mites.

Sprays to control Pacific mites should be applied in time to prevent explosive increases that come with 90° to 100°F weather. Often a second spray will be needed; the need for this will depend on how carefully the first spray is applied to give good coverage, the acaricide used, the concentration, the gallons per acre used, and the number of predatory mites in the vineyard. The Pacific mite has become resistant to many of the acaricides registered for use on grapes, especially if the same chemical has been used year after year. Having developed a resistance to one acaricide, the mites may be resistant to (or may quickly become resistant to) closely related chemicals. This does not mean that resistance to one organophosphorus acaricide automatically confers resistance to all organophosphorus chemicals. It is probable however, that development of resistance to each new organophosphorus chemical will be faster than it was to the first such acaricide.

Special attention should be given to securing good coverage on the lower leaf surface. Poor coverage will give poor results regardless of the material used. Even systemic acaricides give better control when applied to give good coverage.

WILLAMETTE MITE

The Willamette mite, *Eotetranychus willametti* (Ewing), is a less serious pest

of grapes and occurs commonly in vineyards throughout California. It generally does little damage north of Fresno, although concern has been expressed in Amador County.

Appearance. To recognize this pest, see the discussion under Pacific mite, page 15.

Development. The Willamette mite is not as particular as to vine habitat as the Pacific mite and is found in greater numbers in cooler areas of the vine, preferring lower, shady foliage. The mites are generally more evenly distributed in the vineyard than is the Pacific mite, although some vines may have heavier populations of Willamette mites. Both species often infest the same leaves of a vine. The seriousness of a mixed population should be judged mainly by the number of Pacific mites present. The presence of Willamette mite in a mixed population appears to increase the effectiveness of the predator, *M. occidentalis.*

The Willamette mite often appears on the vines earlier in the spring than does the Pacific mite. Occasionally, the Willamette mite overwinters in enormous numbers and emerges explosively in the spring just before the first leaf has unfolded from the swollen buds. The life history of the Willamette mite is similar to that of the Pacific mite except for differences already noted.

Injury. With populations of comparable size the Willamette mite causes less burning and defoliation than does the Pacific mite. Willamette mite injury usually consists of bronzing and yellowing of the leaves. Heavy populations of mites emerge from hiberation, cluster on the swollen buds, and feed extensively on the first small leaflet that unfolds. Under this attack the leaf turns black and dies—sometimes the leaf may be killed before it reaches an inch in diameter. The mite then moves up to the next leaf, which suffers a similar fate, until 8 or 10 leaves have been killed on each shoot. With lower infestations, the young shoots may be bronzed and distorted.

Willamette mite on grape leaf. (Photo by F. E. Skinner.)

Control. The same predators that attack the Pacific mite also attack the Willamette. Also, the predatory mite, *Metaseiulus occidentalis* (Nesbitt), is the most effective. The same problems and considerations concerning the integrated chemical and biological control of the Pacific mite also apply to the control of the Willamette mite.

OMNIVOROUS LEAF ROLLER

The omnivorous leaf roller, *Platynota stultana* Walsingham, is a relatively new pest on grapevines. The fact that it has been found associated with over 80 host plants, the present lack of really effective natural enemies in vineyards, the lack of susceptibility of the insect to many available insecticides, and its direct attack upon the berries, make it a very serious pest of grapes. It has been collected from the southern to the northern tip of the central valley.

Omnivorous leaf roller egg mass on grape berry. (Photo by F. L. Jensen.)

Larva of omnivorous leaf roller. (Photo by F. L. Jensen.)

The larvae of this insect are often confused with those of the grape leaf folder, *Desmia funeralis* (Hbn.). Both wiggle vigorously when disturbed and fall from the leaf. The grape leaf folder larvae are most apt to fall freely, while the omnivorous leaf roller larvae most always drop on a fine thread which they spin.

Appearance. The adults have a typical bell-shaped outline when the wings are folded over the body. Adults are about $\frac{1}{2}$-inch long, although the length is variable. The basal part of the forewing is a dull chestnut brown while the outer half of the wing is a yellowish lighter brown. The hind wings are a dark gray brown. The males are somewhat smaller than the females. The wing expanse is from $\frac{9}{16}$ to $\frac{11}{16}$ inch. The long snout-like palpi extend forward from the head in characteristic fashion.

Development. Live moths have not been observed and traps for virgin females have not caught male moths in severe winters. The winter is passed mostly in larval stages in and around "nests" of webbed leaves of green plants such as alfalfa, roses, etc., and in rotting grapes or in dried grapes ("mummies") on the ground or on the vines. The larvae probably do some feeding on warm winter days, but do not become adult unless they are moved to a warmer environment. Other lepidopterous larvae may be found in the dried grapes. In spring some of the omnivorous leaf roller larvae in the dried grapes pupate, while others emerge and feed on grape leaves before pupating. The pupae wiggle part way out of the mummies or out of the nests of leaves before the adult emerges. Thus, these empty pupal cases may be seen easily. The moths are night fliers and the males, especially, are attracted to lights. Greater flight activity is observed on warm evenings. The adult females live about 10 to 13 days, depending on the temperature, and the males about 10 days. Eggs are laid at dawn or at twilight on the upper surface of the foliage and on the berries. The females may lay from 200 to 300 eggs in masses on the leaves, although on the cotton plant these masses averaged 91 eggs. The eggs overlap each other like shingles or fish scales. The egg contents are green and easily overlooked when deposited on green leaves, which is the usual oviposition site on grapevines. On hatching (4 to 5 days after oviposition) the yellowish white or creamy larvae disperse quickly and wander for about 24 hours before feeding. They feed in protected places such as in leaf rolls made by the grape leaf folder, or where two leaves are touching. Later, either old

Grapes damaged by omnivorous leaf roller larvae. (Photo by F. E. Skinner.)

or young leaves are webbed together to form nests. Nests may also be made by webbing leaves and immature grape flower inflorescences together, and still later by webbing very young berries in the bunches. One larva may build several nests. On grapes, the first two larval instars have very dark brown or black heads and prothoracic shields. There appears to be only five larval instars, of which the last three are a brownish to yellowish green with a dark median dorsal stripe. Larvae feeding on rotted bunches and particularly on moulded berries become very dark. The head capsules and prothoracic shields are brown. The primary setae are borne on prominent tubercles which are chalky white and slightly convex. This is not the case with setae on the larvae of the grape leaf folder.

The larvae overwinter in various stages of development. Depending on temperature, pupation starts in February or March and the first moths emerge in early to late March. There are four or five periods of peak flight activity. These are commonly followed in 7 to 10 days by periods of abundance of recently hatched larvae. In 1968 there were five periods of abundance of very young instars indicating generations starting in May, late June, late July, late August, and late September or early October. Larval development on grapes is completed in about 3 weeks.

The omnivorous leaf roller may increase on weeds in the vineyard during the summer. Ornamental and other plants such as oranges, sugar beets, plums, peaches, walnuts, cotton, and alfalfa are also infested.

Injury. From March to June the larvae usually make nests on the lower leaves where they do but little damage. In late May and June the larvae infest newer foliage and flowers. At the start of the ripening of the fruit more and more larvae are found in the bunches. About 50 per cent of larvae are in the bunches by August 1 and 80 per cent are on the bunches by September 1. The longer the berries are left on the vines, the more likely they will be infested. Thus, the later varieties are more subject to infestation. More of the eggs are laid on the fruit in August and September and the larvae often web and feed where two berries touch. Sometimes the larvae bore into the grape stems. Feeding in the berries by the omnivorous leaf roller provides excellent sites for *Drosophila* (vinegar fly) feeding and oviposition. Also dried fruit beetles are attracted. These and other secondary feeding insects bring in spoilage microorganisms and the resulting bunch rot is the most serious damage related to the omnivorous leaf roller. Bunches infested with the omnivorous leaf roller may comprise from 60 to 85 per cent of total rotten bunches.

Control: biological. Workers have reported several parasites and predators of the omnivorous leaf roller on other crops. On grapes in the Fresno area, the most effective larval parasites are an eulophid wasp and a tachnid fly. These accounted for about 80 per cent mortality of overwintered larvae in some vineyards in 1969.

Control: chemical. With several generations per year, the resurgence of the survivors of an insecticide treatment may result in damaging numbers of this pest later in the season. Because of its wide plant-host range, a treated vineyard may be reinfested from a nearby source. Nevertheless, chemical treatments in early season have often proved successful, and also have the advantage of sometimes permitting use of selective insecticides and timing of application that may be least disturbing to the natural enemies of the spider mites and grape leafhoppers. Some of these insecticides are restricted in time of application—e.g., "Do not apply after edible parts start to form." Experience with these types of insecticides suggests that application be as late in the season as government regulations permit.

Many available insecticides registered for use on grapes later in the season do not give good control. Obviously, good spray coverage of the berries gives better protection. Still, if most eggs are laid on leaves and the first feeding (or, at least, the first possible contact with an insecticide) is on the leaves, then good leaf coverage is also important. As the berries grow, good insecticide coverage becomes more difficult and inside coverage of tight bunches is almost impossible. It appears that in the Fresno area early July may sometimes be the last opportunity to get good coverage of berries. This timing for a chemical control application also appears to coincide with the appearance of younger, easier-to-kill larvae in some years.

In considering an insecticide treatment, one should allow for the possible effects of the insecticide on natural enemies of Pacific mites. The choice of a possible compromise chemical may give somewhat less control of the omnivorous leaf roller without destroying most of the predaceous mites.

Since the omnivorous leaf roller overwinters in grape mummies, all mummies should be removed from the vines and trellis wires and disked into the soil before buds begin to grow in spring. French plowing kills many larvae that have overwintered in mummies in rows on the ground beneath vines.

GRAPE LEAF FOLDER

Grape leaf folder adult female. (Photo by F. L. Jensen.)

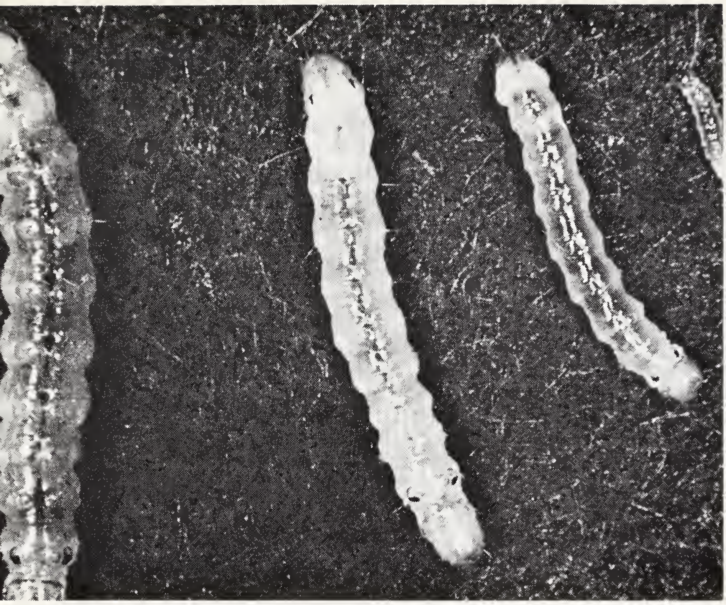
For some grape growers in certain years, the leaf folder, *Desmia funeralis* (Hbn.), is the most serious pest. These moths fly about on the approach of darkness and continue to fly all night if the temperature is high enough. The greatest damage is caused by feeding on the ripe table grapes.

Appearance. The adult grape leaf folder is dark brown, almost black, with a wing expanse of about 1 inch. The forewings in both sexes have two white spots. The hind wings of the female also have two white spots, while those of the male have only one irregularly shaped, large white spot. There are two white bands across the abdomen in both sexes. The male antennae are thickened or knotted in the center; female antennae are smooth.

Development. Three periods of flight occur each year in California, thus indicating three broods. The first moths of the season emerge from pupae that overwintered. These moths occur from early May until the last week in May in the Fresno region. During this period the small, flat, irridescent, elliptical-shaped eggs (about $\frac{1}{32}$-inch long) are laid on leaves in places protected from the wind. Vines sheltered by any type of windbreak are preferred for egg laying. Thus, leaves from vines with good foliage, especially mature sheltered leaves, show more eggs than do leaves of weakly-grow-

Average moth flight periods and time required for completion of various developmental stages of the grape leaf folder at Fresno

Brood	Moth flight period	Time required for eggs to hatch	Total time in larval stages	Total time in pupal stage	Time required egg to emergence of moth
First	April 2 to May 24	10 to 17 days	3 to 4 weeks	10 days to 2 weeks	$6\frac{1}{2}$ to $7\frac{1}{2}$ weeks
Second	June 15 to July 15	4 to 5 days	2 to 3 weeks	7 to 11 days	4 to 5 weeks
Third	August 3 to September 5	4 to 5 days	3 to 5 weeks	overwinter	



Larval stages of grape leaf folder. (Photo by F. L. Jensen.)

ing vines. Eggs are also laid on water sprouts or "suckers." It is in these sheltered places that the moths rest during the day.

Eggs are usually laid singly on leaves, often in the angles between a vein and the leaf surface. Eggs laid in spring hatch in 10 to 17 days, depending on temperature. At first the young worms, or larvae, feed in groups between leaves that have been webbed together; this feeding is of a skeletonizing type. After about 2 weeks the larvae feed singly in pencil-sized leaf rolls which they make by spinning strands of silk from the edge of the leaf to points near the center. As the strands dry, they contract and bend the edge of the leaf. Other strands are then made that curl the edge of the leaf into a roll. The upper leaf surface almost always forms the outside of the roll.

The larvae feed on the free edge of the leaf inside the rolls. Before becoming full-grown each larva makes two or more rolls, the newer ones being made farther out on the canes. The larvae have a pale yellowish-green, translucent appearance. As soon as feeding starts, the ingested leaf tissue gives the larvae a bright green color. The larvae molt five times; when they show a distinct spot near the posterior end of the body, they are in their last stage, the one in which most of the feeding is done. When disturbed, larvae

Leaf roll caused by grape leaf folder larvae. (Photo by H. Kido.)

Overwintering grape leaf folder. (Photo by H Kido.)

wiggle vigorously and fall to the ground.

After reaching full growth, the larvae make a small leaf fold or envelope at the edge of the leaf; this tightly-webbed leaf fold is partially cut away from the leaf. Inside the fold, the larvae change into pupae. Moths emerge from the pupae, mate, and lay eggs, thus starting another brood. Moths emerging in summer lay almost all of their eggs on previously-infested rolled leaves—this tends to concentrate the infestation on vines where eggs were laid in spring. However, vineyards may become infested by moths of the second and third flights, with resultant serious larval infestations. The different larval stages overlap least in the first brood, but larvae of all five stages overlap late in the growing season. When dried leaves fall to the ground, or soon after, the pupal envelope of the third brood breaks away from the leaves and passes the winter among dead leaves and other debris. Some third-brood larvae may pupate in loose bark on the trunks of vines.

Injury. The rolls made by the larvae reduce leaf area, thus restricting leaf food production for the vines. In severe infestations, vines may be weakened and defoliation may expose berries to sunburn. Severe damage usually occurs only with the second and third broods. Third-brood larvae in heavy infestations may feed in the bunches, breaking the skins of the berries and thus permitting entrance of other insects and spoilage microorganisms.

Control: biological. Serious outbreaks of the grape leaf folder have been cyclic, with heavy infestations in 1945, 1952, and during 1954 to 1959. Several parasites tend to keep this insect from becoming a major, more widespread, and annually recurring pest. The parasite *Microbracon cushmani* Mues., is generally believed to be the most effective. These parasites usually increase in summer and reduce the size of the third brood of leaf folders to such small numbers that little injury is done. Insect predators and birds also help to reduce leaf folder population. Suckering and leaf-thinning removes many of the eggs of the grape leaf folder, and is of some benefit in reducing the infestation.

In the eastern U. S. this pest is attacked by several parasites not present in California. If these parasites can be established in California, they may be more effective than those already present. Two promising species from the east were colonized and recovered in 1970 in Fresno County, but more time will be required to determine whether they are permanently established.

Control: chemical. For insecticidal control the application should be made when the bulk of the brood makes its first leaf roll—a period of not more than 4 or 5 days. First-brood control is rarely necessary in the southern San Joaquin Valley. Except in a very few vineyards, an infestation requiring control is no indication of necessity for control the following years.

A disadvantage of first-brood control is that vines are growing rapidly, which increases the chances that a larva will make its second roll on an untreated leaf. Also, in a year of generally heavy infestation there is a greater chance of infestation from moth flights from other vineyards.

The best times for insecticidal treatment are: first brood at bloom, second brood from early to mid-july, and third brood from late August to early September in the southern San Joaquin valley. For best results the insecticide should be applied to control the very young larval stages—this timing is critical for materials of short residual effectiveness. The numbers of leaf rolls a vine can tolerate is not known; in the southern San Joaquin valley perhaps 200 is near the economic threshold. Applications for control of second- and third-brood larvae should give good coverage to upper and outer portions of the vines.

ORANGE TORTRIX

The orange tortrix, *Argyrotaenia citrana* (Fernald), has also been called the "apple skin-worm" in northern California coastal counties where it has been a pest of several deciduous fruits. It has been a pest of citrus only in coastal and intermediate areas and is rarely injurious in warmer, dry areas farther inland. From 1968 to the present, this insect caused considerable injury to wine grapes in the Salinas valley. It has not been reported to be a serious pest of grapes previous to 1968.

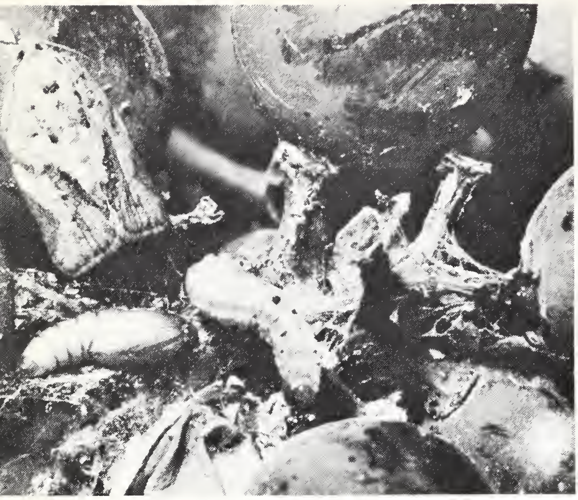
Appearance. The adult moths are a brownish or a buff color with a chevron or saddle of darker coloring across the folded wings. At rest, the tips of the wings flare out a little like a bell. The female moths are about 10 mm long and the males somewhat shorter.

Development. In the Salinas valley the generations overlap. In winters of heavy infestations, larvae of various sizes are readily found feeding on soft tissue under the bark on canes where the bark is split or broken (due to twisting of the canes where they are tied to trellis wires). The larvae are also found in older bark on the vines, in weeds and grasses in the vineyards, and in grape clusters left on the canes after harvest. Adults are present and may be seen flying on warm days. Eggs have been found on the vines in February.

In early spring, larvae tend to occur in more advanecd stages and to feed on or in the swollen grape buds. As shoots develop, the larvae feed on portions of the shoot and on leaves which they web together. Later, many larvae are found in the young berry clusters in which the berries are webbed to form nests. Larvae are usually solitary feeders. In summer, larvae infest the bunches and the leaves and they are more difficult to find.

Eggs are laid on smooth surfaces of the plant, generally on the top surface of the leaves, but also on stems, canes, and berries and are deposited in masses so that they overlap like shingles. When first laid, eggs are pale, flat, and oval, and have a finely reticulated surface. The eggs turn darker as the embryos develop. after hatching, the egg shells appear as a whitish patch. Females may lay about 200 eggs at a time, and these are divided into several masses.

When first hatched the larvae are about $\frac{1}{16}$-inch long and they grow to a little less or a little more than $\frac{1}{2}$-inch long when fully grown. The head, thoracic plate, and the body are straw colored though the body may sometimes be



Orange tortrix adult, larva and pupa. (Photo by Lorry Dunning.)

greenish, dark gray, or smoky colored. They are very active and will wriggle away backwards or sideways when disturbed, or they may drop to the ground or remain suspended (from a leaf) on a silken thread which they can ascend. On citrus, there may be from five to seven larval instars before pupation. At constant temperatures of 45° to 85°F, the number of days required from egg to adult varied from 236 to 44, respectively.

The pupa is about 8 mm long and light brown. The insect pupates in its last larval nest or feeding location. By the time the adult is ready to emerge, the pupa has often worked itself to the outside of the nest, or nearly so. The detailed seasonal history of this insect in grape-growing regions has not been determined completely.

Orange tortrix damage to berries. (Photo by Lorry Dunning.)

Injury. Larvae feed on berries and stems, causing berry drop and stem girdling. Pupae may contaminate the clusters, and larval feeding may result in spoilage.

Control: biological. The orange tortrix has a complex of natural enemies in California, but their role in the Salinas valley situation is not yet understood. One large vineyard in the area has experienced no problem with orange tortrix, while another vineyard only a few miles distant has had a substantial infestation. This pattern suggests that ecological factors are important in determining the local abundance of orange tortrix.

Control: chemical. The presence of the various stages of the insect during the growing season, and the habit of the larvae of living in grape bunches, creates a serious problem in protecting the bunches with insecticides. The foliage (particularly on vigorous vines) interferes with applications and makes spray coverage of berries difficult. As berries grow, it becomes more difficult to mechanically contact the stems and inner surfaces of the berries with insecticides—especially in those varieties where the bunches are tight. Thus, the places where the larvae are most often found are difficult to spray when control is most urgent. Insecticides having a fumigant effect are desirable.

Where sprinkling irrigation systems

wet the vines deposits of insecticides are removed more rapidly, and the value of highly persistent insecticides may be reduced. Sprinkling irrigation and insecticide application should be minimally disruptive of good insecticidal control, and this appears to be easier to achieve when using short-life insecticides.

WESTERN GRAPE SKELETONIZER

Caterpillars of the western grape skeletonizer, *Harrisina brillians* B. and McD., are gregarious, living in close groups on the lower surfaces of the grape leaves. The pest was first found in California in 1941 (its native home is probably Mexico). Two years after its discovery in California it destroyed as much as 90 per cent of the crop in some vineyards in San Diego County. The first generation of moths which emerge in May and June can produce enough worms to defoliate a vineyard by early July.

Appearance. The caterpillar of the western grape skeletonizer is yellow with two prominent, purplish transverse bands and several narrow black ones. Almost every body segment has four tufts of long black spines. These spines are poisonous and when they come in contact with human skin will raise welts similar to those produced by nettles. The head is small, retractible, and black. When caterpillars are full grown and ready to transform to adult moths they are about ½-inch long and taper slightly toward both ends.

The adult moth has long, narrow wings which it folds over its back when at rest. The abdomen is long and tufted at the posterior end in the male. Adult color varies from dark metallic bluish-black to greenish-black. When the wings are spread, they measure 1 inch from tip to tip.

Development. When the caterpillar is fully grown it spins a silken cocoon in which to pupate. The cocoons are irregular, dirty-white capsules and may be found in the trash around the base of the vine or under loose bark. If the cocoon is carefully opened, the light reddish brown pupa may be removed intact. It can move the end of its body around in a circular motion. After emerging from the cocoon, the adult moths mate and the female lays her yellow, capsule-shaped eggs on the lower leaf surfaces, in groups

Eggs of western grape skeletonizer. (Photo by W. H. Lange.)

Above, cocoons of western grape skeletonizer. (Photo by W. H. Lange.)

Left, larva of western grape skeletonizer. (Photo by Lorry Dunning.)

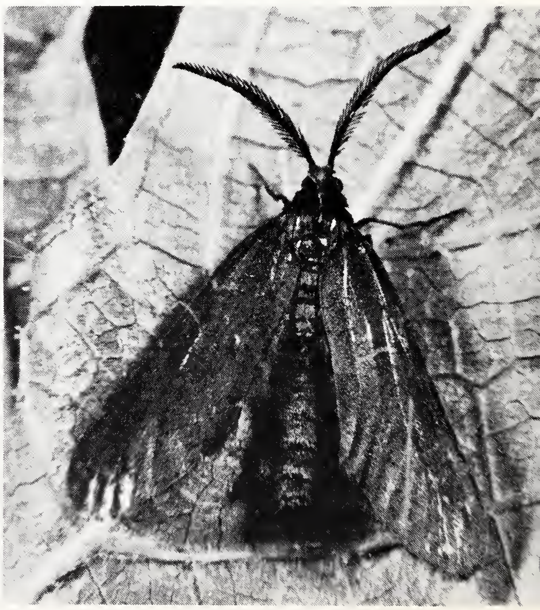
about as large as a nickel. There are three generations per year.

Injury. During their progress across a leaf, caterpillars line up side by side and eat the lower epidermis and green part of the leaf, leaving the upper epidermis intact like a window. As they become larger they disperse over the vine and eat the upper epidermis also, thus making large holes between the larger veins of the leaf.

Control: biological. In San Diego County parasitism by the tachinid fly, *Sturmia harrisiniae,* and the braconid wasp, *Apanteles harrisinae,* reduce infestations of grape leaf skeletonizer significantly. A virus disease is also important.

Control: chemical. Several localized infestations of this pest have been found in northern California, presumably by accidental introduction. In each case the infestations were surveyed by the California State Department of Agriculture, treated until no live pests could be found, and will be continually inspected for several years afterward until the infestation is declared eradicated. At present, most infestations are in the final stages of post-treatment inspection. Other infestations will probably be found in northern California in the future.

Adult western grape skeletonizer. (Photo by Lorry Dunning.)



GRAPE ERINEUM MITE

The damage caused by the grape erineum mite, *Colomerus vitis* (Pgst.), is first noticed in early spring. At this time infested young leaves show bright pinkish or reddish swellings or galls on the upper surfaces. That portion of the leaf beneath the gall is concave on the underside and densely lined with a felty mass of curled plant hairs. These felty patches are called "erinea."

Appearance. The erineum mite can be seen only under magnification, the adult female being about 8/1000-inch long and less than 2/1000-inch thick. Its body is elongated, with short legs attached near the anterior end.

Development. The mites live and reproduce among the masses of abnormal leaf hairs that the plant produces in response to their feeding. If uncontrolled, they may increase enormously in these erinea. Some of the mites move to younger leaves and establish new erinea and new colonies.

Leaves less than ½ inch in diameter are apparently best suited for this purpose. Mites do not produce erinea on larger leaves. From the middle of August to leaf drop, adult mites migrate to the axils of the leaves and crawl under the bud scales—the migration occurs only at night. The winter is passed in the buds. In spring, the mites move to new leaves to start their seasonal cycle over again.

Injury. In heavy infestations the entire lower surface of the leaf may be covered with erineum, and in even more severe cases the upper surface of the leaves and even the tendrils may show this abnormal growth of plant hairs. In a short time the swellings on the upper sides of the leaves turn to the normal color of the leaf. Later in the season the erineum turns yellow. then, in August, brown.

Although the erineum mite often causes the grape grower some concern in spring, little damage from this pest has occurred in vineyards. The mite is generally distributed throughout California and has been taken from almost every cultivated variety of grape.

Control: biological. Thrips larvae and predaceous mites of *Metaseiulus* species have been observed feeding on the grape erineum mite.

Galls formed by erineum mites. (Photo by H. Kido.)

Reverse sides of leaves shown in photo on left.

Control: chemical. Chemical control is highly effective.

Grape bud mite strain

In many grape-growing areas in California, there occurs a strain of erineum mite, *Colomerus vitis* (Pgst.), which lives in grape buds.

Appearance. This strain in indistinguishable from the erineum mite described previously except that it does not live on leaves or cause leaves to produce felty patches of plant hairs.

Development. Adult females overwinter at various depths in grape buds. Egg laying starts as buds begin to swell in spring. As new shoots elongate, many eggs and young mites are carried out with the bud scales. These scales become bracts at the bases of the leaf petioles close to the new buds. As new buds develop, the mites move under the bud scales.

In spring, the mites apparently move about so that any bud on the cane may become infested. More mites, and deeper penetration of mites into buds, usually occur on the basal portion of the cane. The greatest numbers of mites are found in fall, and the population gradually decreases in winter. Pruning removes many mites but sources of buds with greatest adult mite reinfestations are left on the vine.

Injury. Mites feed at the bases of outer bud scales, causing blister-like growths on the inner surfaces, and may feed deeper into the buds. The first type of feeding does not cause injury, but extensive feeding on the embryonic tissues of grape buds causes malformations of the maturing structure. Similar malformations may be caused by other organisms or conditions.

The shoot apex of opening buds may be so damaged by bud mite feeding that it dies, but a secondary or tertiary growing point in the bud may give rise to a normal cane. If the shoot is killed by mites, one or more lateral buds may take over. The extent to which such canes produce berries depends on the grape variety. Severity of injury varies directly with the number and location of mites in the buds. The injury may be recognized by the typically abnormal basal leaves, length of internodes, and number of canes with crop.

The frequency of buds damaged seriously enough to reduce the number of berries per cane has not been observed to be sufficient on a vine or vineyard basis to cause commercial loss.

Suppression of the growing shoot by grape bud mites. (Photo by R. O. Schuster.)

Damage to Barbera vines by mites of the leaf curl strain. (Photo by F. L. Jensen.)

Leaf curl strain

In 1948, a leaf curl strain was reported on Black Corinth vines near Modesto. In August 1972, near Burrell (about 25 miles west of Kingsburg) several hundred acres showed slight to severe injury. Injured leaves varied from nearly normal with a slight downward roll to leaves less than a quarter normal size with so severe a downward roll as to form a rough ball. Internodal length was also reduced, with scarring sometimes noted on the internodes. Sideshoot growth was promoted; over-all growth was stunted, although the vines had made excellent growth up to about early August.

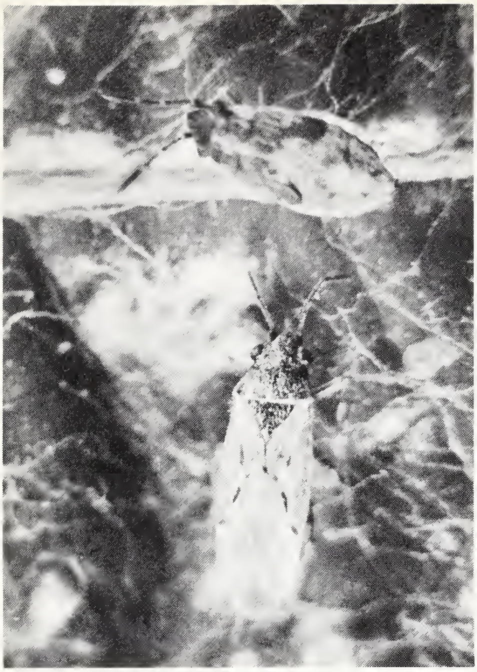
These new wine grape plantings included Barbera (the most severely affected), French Colombard, Rudy Cabernet, and Petite Sirah. An application of an insecticide for grape leafhoppers apparently controlled the erineum mites because new growth on the sprayed Barbera vines was normal compared to adjacent untreated vines which had persistent symptoms. The severity of these symptoms seemed to be declining in mid-September, although some shoots showed tip leaves being affected up to the end of the season. Presumably, control could be obtained by instituting a normal dusting program for mildew control.

FALSE CHINCH BUG

Although false chinch bugs, *Nysius raphanus* (Schill.), are not yearly pests, they may breed in countless millions in grassland and pastures in early spring. When the grass dries up, the bugs migrate in search of green food and a vineyard situated in their path may suffer serious injury. When they are forced to leave the grassland they are mainly in the wingless young stage, and consequently they migrate by walking. A number of winged adults are present also, but instead of flying they march along with the wingless immature ones.

Appearance. Adults are about $\frac{1}{8}$ inch long, and are light or dark gray. The young are gray, with a reddish-brown abdomen.

Development. The eggs are laid at random on rubble in the soil or in cracks in the ground. All stages may hibernate, but



False chinch bugs on the lower surface of a grape leaf. Above: Immature bug. Below: Adult with wings. (Photo by H. Kido.)

the great majority pass the winter in the immature stage. There are about six generations each year, and population pressure—which exhausts the food supply in the fall—may produce fall migrations.

Injury. When a horde of false chinch bugs invades a vineyard, they swarm up the trunks of the vines to the leaves where they immediately begin to suck the juices. Within 3 hours a healthy vigorous vine may wilt and turn brown as though burned.

The most serious and destructive migrations occur in May and June as the grass and weeds dry up, but there are occasional migrations in September and October.

Control: chemical. Control of this pest may be achieved by disking up the weeds in and nearby the vineyard to prevent buildup of the bugs. Later, the grassland from which the bugs are migrating may be burned off if this is feasible. (Uusally, burning is not feasible and chemical control must be used.)

Bugs migrate mainly in one direction and the wilted vines along the edge of the vineyard clearly show the line along which they are entering. It is possible to lay down a chemical barrier about 30 feet wide to prevent farther migration, or the vines may be sprayed or dusted with insecticides.

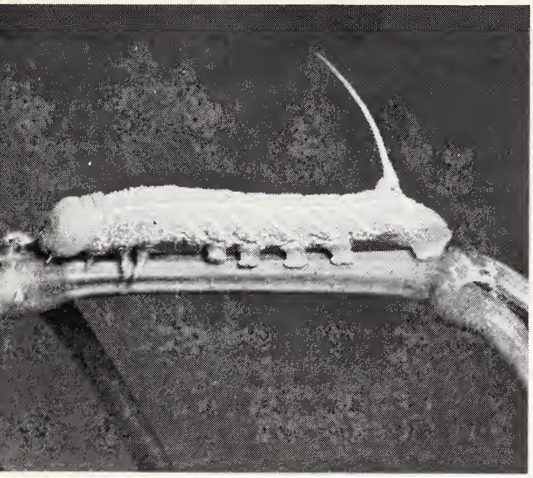
GRAPE RUST MITE

The feeding of the grape rust mite, *Calepitremeris vitis* (Can.), on the surface of leaves causes a yellowing of the white grape varieties which closely resembles the appearance of leaves slightly injured by the Pacific spider mite. On dark grapes, injured leaves become a brilliant red.

These light-amber mites are microscopic in size, and under a 14-power hand lens they appear wormlike. They are broader at the front end and move about slowly. The mites overwinter in grape buds and begin egg-laying in spring. The emerging young infest leaves and multiply on them during the growing season. They may be found on both upper and lower surfaces—on the upper surface they tend to cluster along the main veins on green tissue.

If unchecked, the mites would attain such enormous numbers as to cause serious defoliation. Fortunately, they are easy prey to their many natural enemies, and control is rarely necessary.

ACHEMON SPHINX MOTH



Achemon sphinx larva before losing posterior horn. (Photo by H. Kido.)

The achemon sphinx moth, *Pholus achemon* (Drury), is rarely seen because it flies at night and hides during the day. It feeds on the nectar of flowers, especially petunias.

Appearance. The moth is about as large as a hummingbird and hovers in the air outside of a flower while feeding.

Achemon sphinx moth adult. (Photo by H. Kido.)

The caterpillars of the achemon sphinx are about $3/16$-inch long when they first hatch. They have a large black posterior horn that is longer than the body. When about $1/2$-inch long the caterpillars take on various colors. Some remain green, like the young worms, but others become pink, tan, or brick red; at this time they lose the horn and only a dark button remains in its place. They have at least six diagonal white stripes on their sides, four of which are above each abdominal leg. When fully grown, the caterpillars are about 4 inches long and resemble their close relative, the green tomato worm.

Development. The achemon sphinx moth lays large green eggs singly on the upper surfaces of the outer grape leaves. The eggs hatch 6 to 9 days after they are laid. At higher temperatures the incubation period is shorter. Immediately after hatching, the caterpillar eats a smooth round hole in the leaf and crawls through to the lower surface, where it continues to eat small round holes in the leaf.

The caterpillars continue to feed on grape leaves for about 25 days. They then make their way to the ground, penetrate to a depth of 2 to 6 inches, construct a smooth-walled cell, and enter the pupal stage. The pupa is a spindle-shaped, mahogany-brown object about 2 inches long. If any number of these are plowed up during spring cultivation, the grower should be alerted for an outbreak of worms the following summer.

This pest overwinters in the pupal stage in the soil, and the moths emerge from the soil during the first half of May. The second brood of moths appears in the vineyards in early July. The second brood of worms is much more numerous than the first, and their greatest damage is done in August. A generation is completed in about 55 days, and some years there is a third generation.

Injury. This pest is cyclic in appearance—that is, several years of severe damage are followed by several years of negligible injury. In years of heavy outbreak a maximum of 500 worms was found on a single vine.

A large worm may eat nine mature grape leaves every 24 hours. When a vine has been completely defoliated, the worms leave it and may walk a considerable distance to the nearest vine still having green leaves.

Control: biological. There are several parasitic flies (Tachinids) which attack the larvae, and in most years these are a substantial mortality factor for the pest. (It has been reported that in years of heavy infestation skunks entered some vineyards to dig up and eat the pupae.)

Control: chemical. Chemicals applied for control of the grape leafhopper or grape leaf folder have apparently also controlled the achemon sphinx. If chemical control is necessary, the insecticide should be applied without delay because mature worms are much more diffcult to poison than are small ones.

WHITE-LINED SPHINX MOTH

Another pest that occasionally attacks grapes is the white-lined sphinx, *Celerio lineata* (Fabr.), which is closely related to the achemon sphinx.

Appearance. This pest derives its name from the broad diagonal white stripe on the front wings of the moth. Larvae of the white-lined sphinx are bright green with broken, black longitudinal stripes down the back. Occasionally black larvae occur. They are about the same size as the achemon sphinx, but in addition to their variation in color and marking they can also be distinguished by a long yellow horn at the rear end of the body which remains throughout the larval period.

Development and injury are similar to those of the achemon sphinx moth except that the larvae of the white-lined sphinx may be produced outside of, and migrate into, the vineyard.

Control. Control can be mechanical—that is, by a ditch barrier with the steep side next to the vineyard—or by insecticides applied to border grapevine rows. An insecticide dust can also be used in combination with the ditch.

GRAPE WHITEFLY

The adult whitefly, *Trialeurodes vitatus* (Quaintance) is a mothlike insect about $\frac{1}{16}$-inch long. It can be readily identified by its size and intense whiteness, which is caused by a dense, white waxy powder covering body and wings.

Development. Adults lay their eggs on upper or lower surfaces of grape leaves. The eggs, so small they can be seen only with a magnifying glass, are attached to the leaf by a short stalk. After hatching, the larvae crawl a short distance then settle down to a motionless existence, usually on the upper surface of the leaf. At this stage they are difficult to distinguish from scale insects, especially young soft brown scale. They can be distinguished if the leaf is bent sharply beneath them, thus breaking the seal to the leaf, allowing the air to go beneath the insect and making it more visible. (This is not

true with scale insects.) The larva has a lemon-yellow body circled by a narrow white waxy fringe perpendicular to the leaf. During transformation to the adult stage the larva is dark brown with a white fringe. When larvae are fully grown they transform to the adult stage and emerge, leaving their discarded shells attached to the leaf.

There are several generations a year. The pest overwinters in the larval stage on various evergreen shrubs that compose our chaparral. In spring, adults may fly from chaparral areas to vines and establish an infestation. If vines are infested early in the season, the whitefly may build up to enormous numbers, as it multiplies very rapidly.

Injury. The whitefly injures fruit chiefly by soiling it with sticky excrement on which a black, sooty fungus develops.

Control. Backyard vines are more apt to become infested than commercial vineyards, since ornamental shrubs in the yard may provide a suitable host on which the pest can overwinter.

INSECT VECTORS OF PIERCE'S DISEASE

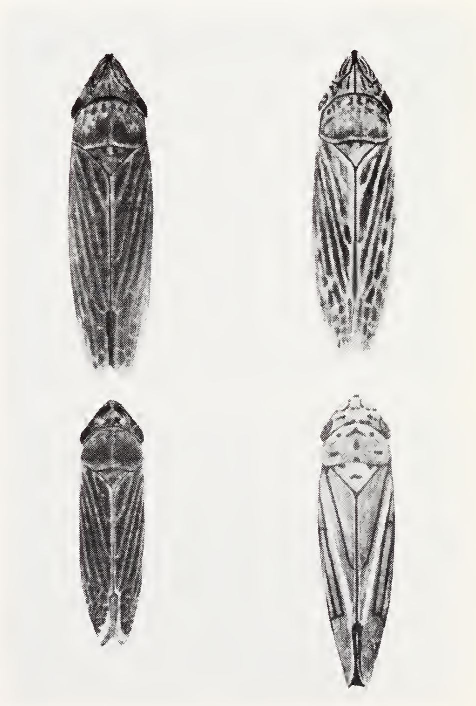
In California there have been two serious outbreaks of Pierce's disease—one between 1880 and 1900, the other between 1934 and 1947—both associated with greater than normal rainfall. In the interim there have been several local outbreaks in the Napa, Sonoma, and San Joaquin Valleys, especially in the Napa Valley from 1961 to 1965.

The bacterium that causes the disease may be transmitted from plant to plant by at least 24 species of insects. Of these, four are spittlebugs. Spittlebugs are so called because the young often surround themselves with a mass of white, wet froth. The remaining 20 vectors are all sharpshooters. Sharpshooters are a kind of leafhopper. The grape leafhopper, however, is not a vector of Pierce's disease.

The symptoms of Pierce's disease of the grape have been described as follows:

"1) Leaf scalding and later drying of the entire leaf, which usually starts after midseason; 2) wilting, withering, drying, and premature coloring of the berries on part of the vine or on the entire vine; 3) delayed foliation of a part of the vine or of the entire vine; 4) interveinal chlorotic mottling of the lower leaves (usually leaves 2 to 8) of

Leafhopper vectors of Pierce's disease of grapevines (magnified about 11 times). Upper left: Green sharpshooter; Upper right: Brown form of green sharpshooters; Lower left: Red-headed sharpshooter; Lower right: Blue-green sharpshooter. (After Henry H. P. Severin.)



the shoots; 5) dwarfing of the shoot growth of a part of the vine or of the entire vine; 6) failure of the canes to mature evenly; 7) gradual dying of the root system; and 8) death of the vine."

Of the 24 vectors of Pierce's disease only three are important in transmitting the disease to grapevines. In the San Joaquin Valley the green sharpshooter, *Draeculacephala minerva* (Ball), and the redheaded sharpshooter, *Carneocephala fulgida* Nott., are of major importance. In coastal regions the blue-green sharpshooter, *Hordnia circellata* (Baker), carries the bacterium to the vines. These and the other vectors transmit the bacterium among the 73 plant species that are hosts and serve as virus reservoirs.

Throughout most of California green sharpshooters are green the entire year, but in certain regions of the state they turn brown in late fall, winter, and early spring. In summer they are green again. The female is slightly over ¼-inch long and the color underneath is paler. The male is smaller, and is dark underneath.

Overwintered adult females lay eggs in weeds and grasses in early spring. The young that hatch from these eggs are much the same shape as the adults but do not have wings. Three broods of sharpshooters are produced each year. This sharpshooter is most easily found in moist locations. Though it prefers to feed on grasses, it has been taken from more than 130 plants.

The redheaded sharpshooter female is about ⅕-inch long and its head is rounder than that of the green sharpshooter. It may be further distinguished by the reddish color of its head, although the body is green. Winter is passed in the adult stage, and there are four broods each year. It is found in somewhat less moist locations than is the green sharpshooter.

Green and redheaded sharpshooters prefer grasses, but they will feed on succulent vine growth in spring. No reproduction takes place on grapevines.

Females of the blue-green sharpshooter are only slightly smaller than those of the green sharpshooter and vary from green to bright blue on top and yellow underneath. There are characteristic black marks on the upper surface.

The blue-green sharpshooter is found in heavy growth along streams, especially along the coast. It also occurs along stream banks in the San Joaquin Valley but does not appear to spread into the vineyards of the area. It feeds and breeds on vines, shrubs, and trees, and is often found on ornamental plants in home gardens. This sharpshooter moves about considerably in seeking succulent food. On grapevines it is most frequently found feeding on the tips of the canes. It passes the winter in the adult stage, and there is but one brood each year.

There is no remedy for Pierce's disease of grapevines. Diseased vines may, however, be replaced with healthy grapevines or layered from nearby older grapevines. The chances of the replants contracting the disease are the same as that of any other plant in the vineyard doing so.

GRASSHOPPERS

Two species of grasshoppers of the genus *Schistocerca* attack grapes. These are the green valley grasshopper, *Schistocerca shoshone* (Thomas), usually found from Bakersfield northward, and the vagrant grasshopper, *Schistocerca vaga* (Scudder), which is found from Fresno southward.

A third species particularly harmful to the vineyard is the devastating grasshopper, *Melanoplus devastator* Scudder, which occurs chiefly in the low foothill

Adult green valley grasshopper, about natural size. (Photo by H. Kido.)

areas in the Sierra and Coast Range and is found through the length of the state.

Various other species are occasionally found in vineyards but rarely cause commercial damage. Their life cycles are similar to the devastating grasshopper's except that they lay their eggs before the fall rains start and are not limited to the foothill regions.

Appearance. The green valley grasshopper is easily recognized by its leaf-green color, red hind legs, and a yellow stripe along the midline of the head and thorax. It is one of our largest grasshoppers. The females are about 2½-inches long and the males measure about 1½-inches.

The vagrant grasshopper is about the same size but is easily recognized by its brown body, brown legs, and a tan stripe along the midline of the head and thorax. The front wings are tan with brown mottling.

In its immature stage the devastating grasshopper varies from straw-colored to brownish-black, with darker stripes on the sides of the head and thorax. The adult averages just under an inch in length, is amber to brownish in color, and has dark markings on the thorax and a row of dark spots on the front wings. The shank of the hind leg is blue at the base and shades gradually to amber at the tip.

Development. Both the green valley and vagrant grasshopper lay their eggs in May. The eggs are laid in masses in a hole in the ground, which the female bores by inserting her abdomen into the ground as far as possible. The eggs are embedded in a frothy material that soon hardens in a sponge-like structure. These egg masses of the grasshopper are called pods. Each female lays several pods. Within a few weeks the eggs hatch into young, wingless hoppers which burrow to the surface and commence feeding on plant foliage. They grow slowly through June and July and reach the winged adult stage in late summer.

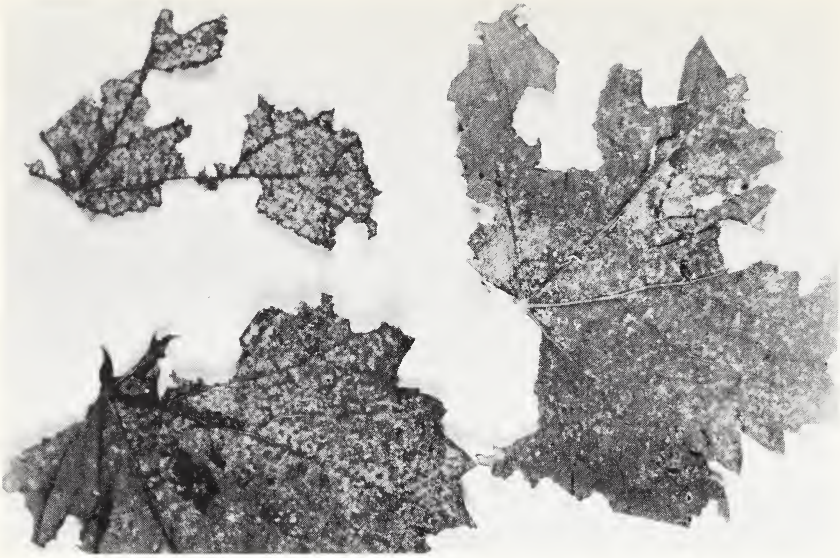
The devastating grasshopper, on the other hand, lays its eggs in the ground in the fall after the first rains. The adults all die in the fall or early winter, and only the eggs survive. The overwintered eggs hatch during the following May, June, and July.

All three species thus have only one generation a year.

Injury. After passing the winter in hibernation in the adult stage, green valley and vagrant grasshoppers become active in spring, when they may enter the vineyards in great numbers and defoliate the vines by feeding on young shoots.

The devastating grasshopper does its damage usually in mid- to late summer when grasslands dry up. By this time the winged adults are present, and they

Devastating grasshopper, about natural size. (Photo by H. Kido.)



Damage caused by devastating grasshoppers feeding on leaves.

fly from their breeding grounds into the vineyards in search of green foliage.

Chemical. Because there is only one generation per year, it is often practical to spray vineyards with an effective short-lived insecticide after the eggs have hatched. Of course, large insects are more difficult to kill with stomach poisons than are small ones. After harvest, one may use longer-lasting insecticides.

If large numbers of wingless hoppers are found on range land adjacent to the vineyard, it may be feasible to control them by using poison bait.

HOPLIA BEETLE

Hoplia beetles, *Hoplia oregona* Le Conte, are often noticed first on the flowers of many plants. They are particularly attracted to white flowers—roses, lilies, orange blossoms, and the blossoms of deciduous fruit trees. When disturbed, these beetles are quick to feign death and fall to the ground, even though they are strong fliers.

Appearance. Adults are ¼-to ⅓-inch long and are robust. The abdomen of the female is thicker than that of the male, which is almost flat. On the upper side the beetles are mostly reddish-brown with darker heads; the underside is silvery and shiny. Large variations in color and size occur, however, even among beetles that have emerged from a limited area of ground.

Development. During June the beetles die of old age after laying their eggs in the ground. The larvae hatching from the eggs are grubs that feed on the roots of alfalfa, lawns, and other plants, including roses. The grubs are whitish and curved in a C shape. They have six short legs at the anterior end and a swollen bulbous posterior. The grubs pupate in the soil in early spring and change over into the adult form. On emerging from the soil in spring, the new adult beetles often leave round exit holes. They immediately fly some dis-


Left: Adult grape hoplia beetle (about 4 times natural size). Right: Larva or white grub of grapevine hoplia. (Photos by H. Kido.)

tance to flowers and vines to feed and mate. (Often good sources of food are passed over in this dispersal flight.) Some must return to lay eggs, however, as hoplia beetles have been observed to emerge year after year from the same limited area.

Injury. The beetles often feed in groups so that severe damage in a vineyard may be spotty. In certain regions of the San Joaquin Valley, however, crop loss has been severe.

About the time new shoots are 12-to 14-inches long, the beetles fly into the vineyards and feed on fruit-forms or on developing bunches and young leaves (This usually occurs before the forms are more than 3-inches long). Partial destruction of fruit-forms caused by such feeding results in small, misshaped bunches at harvest.

One or two weeks after their first appearance in the vineyard, certain vines, often at the end of vine rows, may show considerable foliage damage from the gregarious feeding of the beetles. About this time the beetles stop feeding on the forms, and the vines produce foliage so rapidly that the beetles do but little further damage.

Control: chemical. Chemical control is available when needed. In many cases spot treatment will be sufficient.

CONSPERSE STINK BUG

In late summer and early fall consperse stink bugs, *Euschistus conspersus* Uhler, may invade a vineyard in great numbers. They suck the juices from the leaves and petioles, but this results in negligible damage to the vine. They also feed readily on ripening berries and this may cause some crop loss.

Appearance. The adult stink bugs are between $\frac{3}{8}$-and $\frac{1}{2}$-inch long. They are brown with amber-colored legs on which are distinct minute black spots. The antennae are yellow or pale green. The body is hard and shield-shaped. Adult bugs have wings and can fly considerable distances.

Development. These pests pass the winter in the adult stage, hibernating

Adult consperse stink bug (about 4 times natural size). Note black spots on legs. (Photo by H. Kido.)

under trash on the ground. Emerging from hibernation in April, they feed on many different kinds of annual plants and lay their eggs on these plants. The white eggs are laid in groups of 10 to 20, and each egg has a row of small spines around the top edge. Egg-laying continues through April and May. The young bugs that hatch are wingless and feed on a variety of broad-leafed weeds, especially mustard, dock, mullein, and plantain. Young bugs reach the adult stage in July, August, and September, and in turn lay eggs that develop into adults in September and October. The adults of the second generation (and possibly some of the first) hibernante during the winter.

Injury. Consperse stink bugs feed by inserting their mouthparts into the ripening berries. From each puncture the berry bleeds, forming a brown, sticky, unsightly mass. These feeding punctures cause a rapid internal breakdown of the berry, which soon shrivels and may become moldy.

Control. Invasion of the vineyard occurs near picking time, so control of this pest with chemicals in vineyards may not be feasible because of the possibility of a poisonous residue remaining on harvested fruit. Hordes of adult bugs have been known to enter vineyards in September and early October following late cutting of adjacent alfalfa fields. Similar migrations may occur in midsummer as grasslands and pastures dry up. When large populations of stink bugs are known to exist in fields adjacent to the vineyard, chemical control of the bugs in these fields prior to migration is suggested. Whether or not chemical control may be used in such a case will be determined by the nature and intended use of the crop and the insecticide employed to avoid residue and re-entry problems.

Damage caused by consperse stink bug. Note spots where juice has oozed from stink bug punctures. (Photo by H. Kido.)

GRAPE MEALYBUG

A considerable amount of packable table grapes may be lost because of the unsightly presence of mealybugs, their egg masses, cast skins, honeydew, and the sooty mold that grows on honeydew. The mealybug, *Pseudococcus maritimus* (Ehrh.), is also found on many native and cultivated plants.

Appearance. Adult females are wingless, oval, flattened insects about ⅛–$^3/_{16}$-inch long and appear to be smoothly dusted with a white, waxy secretion. Fine filaments of wax stick out from the margins of the bodies. The filaments at the posterior end are much longer than the others but never longer than half the body length, and become progressively shorter along the sides to the head.

Development. Grape mealybugs pass the winter as eggs or very young stages in or near a cottony egg sac under loose bark on the trunks and arms of the vines. With the approach of spring they move to the bases of the spurs or canes. Soon they move out onto the new growth and feed on leaves, petioles or fruit clusters. By June the mealybugs have matured and are laying eggs. Eggs are laid in a loose, cottony wax sac which the female carries about—the females usually move back to the bark before depositing their egg sacs. Hatching takes place in June and is completed in late June or early July in the southern San Joaquin Valley. Sucker growth touching old wood in the crown of the vines, and grape bunches resting against old wood, make excellent places for the young to feed and develop. It is the June-hatched generation of mealybugs that does the most damage. Some of this generation move out on the leaves and canes, but some stay on the mature wood.

The next brood of eggs are laid in fall

Grape mealybugs on a grape berry. (Photo by F. L. Jensen.)

Black fungus on honeydew droppings of grape mealybugs. (Photo by F. L. Jensen.)

Heavy mealybug infestation on grape berries. Bunch is turned to expose side that was resting on the old wood. (Photo by H. Kido.)

either in the clusters or on the arms and trunk. From these eggs on these older parts of the vine will come most of the overwintering population. There are thus two broods a year. Each female may lay up to 600 eggs.

If the temperature is high enough at the time of the June hatch many of the crawlers may be killed and this sometimes causes a significant reduction in the mealybug population.

Injury. Much of the injury to table grapes consists of unsightly appearance. The honeydew secreted by both young and adult grape mealybugs collects in drops wherever it lands on the vines, and may be found inside the bunches where mealybugs are feeding. Drops of honeydew may collect on bunches in such quantity as to run and drip; the drops are much larger than those of the grape leafhopper, whose honeydew does not collect in sufficient quantity to drip. This sticky liquid supports growth of a black fungus that gives the leaves and bunches a sooty appearance. More seriously, mealybug infestations in the bunches may cause berries to crack, thus permitting easy entry for spoilage organisms. Fruit clusters with recognizable infestations are either rejected in the field or culled out at the packing house.

Evidence of light infestations on raisin grapes is removed in processing. Heavily infested bunches cannot be processed.

Control: biological. Many insect parasites and predators help reduce grape mealybug populations, and in many areas such natural enemies are sufficient to hold this pest in check. However, ants—which often visit the mealybugs to collect the sweet honeydew they secrete—will keep parasites and predators away and permit mealybugs to increase.

Control: chemical. Best results have been obtained from dormant-season sprays. Until the winter of 1970 only three or four insecticides showed promise, and only one has been widely used. Two chemicals can be combined in one spray to control both mealybugs and black measles (whenever two chemicals are combined they must be compatible both chemically and by formulation). Dormant sprays should be applied after pruning. Little difference in effectiveness has been observed between sprays applied in January, February, or March. Sprays may be applied safely to swollen or fuzzy buds before the shoots begin to develop. If the leaves have started to unfold a spray that is less toxic to the plant must be used, but it is difficult to avoid injury by sprays of dormant season strength after the new shoots are more than ½-inch long. At this time of year heavy doses of insecticides are more likely to result in plant injury on warm days.

Dormant sprays must be applied to give thorough coverage of the crown and

arms of the vine. The amount of spray per acre needed will depend on the amount of old wood (and therefore the amount of heavy bark) that is present. Control of mealybugs on young vines is easier and requires fewer gallons of spray per acre. A coarse-driving spray and pressures of about 200 pounds per square inch will give a good soaking of the bark. Particular attention should be given to the undersides of the arms where most mealybugs are found. Spraying the trunks of the vines below the crown adds little to control. If the insecticide reduces the number of infested bunches by nearly 100 per cent as compared to untreated vines, there may also be a very significant reduction the second year following treatment. The grape mealybug has developed resistance to at least one insecticide, and increased dosages per acre are needed to give adequate control.

Early spring and summer control treatments have not been as successful as dormant treatments. Dusts are preferred because they do not spot the fruit, but sprays are much more effective. Concentrated sprays applied as fine droplets are less noticed on the fruit than more dilute spray. Applications should be made within 1 to 2 weeks after the midsummer hatch.

VINEGAR FLY

The name vinegar or pomace fly is applied to various species of *Drosophila* but especially to *D. melanogaster* Meig. and *D. simulans Sturt.* These two species are difficult to separate and will be considered together. During the harvest season in vineyards and orchards in Fresno seven species of *Drosophila* were found, but more than 95 per cent were *malanogaster* and *simulans*.

Appearance. The yellowish adult flies are well-known because of their attraction to fermenting fruits of all kinds. They are about $\frac{1}{10}$-inch long and are often seen hovering above garbage cans and cull fruit and vegetable dumps. The eggs have two appendages. The larvae are typically maggot-shaped and are about $\frac{1}{4}$-inch long.

Development. Few vinegar flies survive the winter when fully exposed outdoors. They may survive and reproduce in masses of fermenting material where the inner temperature of the mass is favorable, or indoors wherever fruit is stored. *D. melanogaster* has a life cycle of 7 to 8 days at 85°F but the cycle may take 70 days during the winter. The females live an average of 28 days at 83°F and lay a maximum of 26 eggs per day. The minimum temperature for flight is 55°F and the maximum is 100°F. Temperatures of over 105°F kill adults in a few minutes. Air movement of over 7 miles per hour will restrict its movements. The adults find their food by odor and thus fly upwind. Both adults and larvae prefer to feed on yeasts.

The population of vinegar flies builds up during the growing season on culls and waste of several fruit and vegetable crops grown in the areas nearby the vineyards. This buildup is slowed by hot weather, but if a sudden cool spell or a light rain occurs during harvest, huge populations develop quickly.

Injury. As the grape berries ripen they may be pulled away from their stems (especially in tight clusters) thus exposing the fleshy part of the fruit. Vinegar flies are attracted to such places to lay eggs. After hatching the larvae feed on the berries. Adult flies are also attracted to fermenting bunches. As they fly about they carry numerous bunch rot pathogens from fermenting bunches to previously

uninfested clusters. Their greatest damage to the vineyard is the secondary spread of bunch rot.

Control: chemical. Control of vinegar flies may reduce the amount of rotting bunches from 10 to 12 per cent (by weight) below the amount on untreated vines. Treatment should be started when bunches start to show rot and become attractive to vinegar flies (mid to late August in the Fresno area). Cultural management of fertilizer and irrigation programs, and use of gibberellins to lengthen cap stems, may reduce the number of tight bunches and incidence of bunch rot.

WESTERN FLOWER THRIPS

The Western Flower Thrips, *Frankliniella occidentalis* (Pergande), is commonly found in spring on many plants and flowers. It is highly attracted to grape blossoms and is abundant in clusters during bloom. Occasionally other thrips may be present in grape blossoms, but the Western Flower Thrips is found almost exclusively.

Appearance. These thrips are about $\frac{1}{24}$ inch long and vary in color from yellow to brown. They can be readily seen when dislodged from flowering bunches.

Development. The Western Flower Thrips reaches its greatest numbers on lush vegetation in spring. Grape bloom period coincides with this build-up, and thrips then move into the flowers. Adults lay their eggs on stems in the clusters. There are two immature wingless, nymphal stages. Later, the nymphs drop off the clusters to complete development and thereafter are rarely found.

Injury. The thrips produce scarring and dwarfing of new shoots in early spring but also may be present in the flowers from pre-blooming to the formation of young fruit—a period of more than 3 weeks. Peak population of adults in the bunches are usually found when 50 to 60 per cent of the caps (dried parts of blossoms) are off.

When eggs are laid in the newly-developing berries, a small dark scar surrounded by a lightened area develops. This is called a halo spot. These scars mar the appearance of grape varieties such as Almeria and Calmeria; with Italias the halo spots are not only unsightly but during the latter stages of growth the skin, weakened, by the egg puncture, may crack and lead to bunch rot.

Feeding by the nymphs may cause another type of scarring especially under the caps that sometimes persist on the berries, but caps and scarring may occur anywhere on the berry. Nymphs and adults are found in the clusters at the late bloom stage. From this stage to the shatter stage the adult thrips become

Immature and mature thrips. (Photo by H. Kido.)

Thrips oviposition puncture injury to immature berries. (Photo by H. Kido.)

Injury to berries from thrips feeding on them. (Photo by F. L. Jensen.)

fewer and the nymphs increase markedly in the clusters. At the shatter stage, nymphs under the caps and the first signs of scarring may be observed. By the time the berries are about ¼ inch in diameter both nymphs and adult thrips have dropped to a low level. Apparently, all scarring is finished shortly after the completion of the shatter stage.

Gibberellin accentuates thrips damage to Thompson Seedless grapes, especially the blossom-thinning sprays. Later, berry-sizing sprays of gibberellin do not increase noticeable scarring as much. After cap fall, scarring is not a problem.

Control: chemical. In Italias damage occurs from the beginning of bloom to shatter stage, but most of the damage occurs from 95 per cent bloom to shatter. Probably two early sprays (at 5 per cent and 95 per cent bloom) would be sufficient. Serious injury occurs sporadically depending on the year and vineyard. Insecticides should not be applied unless the problem is known to exist and appearance of the grapes is of great importance.

GRAPE THRIPS

Grape thrips, *Drepanothrips reuteri* Uzel, are tiny insects about $\frac{1}{32}$-inch long. They do their greatest damage by scarring berries and rendering fruit unsightly and unfit for the table market. They also feed on leaves and on green tender shoots.

Development. Grape thrips emerge from hibernation about the time buds begin to open in March. Apparently, only females overwinter in the soil but not under the bark (as reported in other countries). By late March gravid females may be found in buds. Overwintered females feed on the leaves in the spring for about 20 days, during which time they lay many eggs, inserting them shallowly under the skin of leaves and stems. The first larvae (wingless) hatch out early in April. They are amber or yellow, and when mature are about the same size as the adults are.

Leaf damage caused by thrips. (Photo by S. F. Bailey.)

Breeding is speeded up by warmer temperatures of summer, and by mid-summer the grape thrips complete a generation in 22 days. About six overlapping generations are completed each season, and the peak of abundance normally occurs about the last week of July. Adult females are amber to orange in color. Males are smaller and more slender. Both adult sexes are winged. As vine growth slows down, favorable succulent leaves are fewer, and the thrips population dwindles. Adult females survive the winter in small numbers.

Injury. Injury begins when the shoots start to grow, especially in cool weather. Infested leaves are more circular, with greater pubescence on lower surfaces than on normal leaves. Shoots may be severely stunted; in heavy infestations all shoots are stunted. Shoots tend to recover in warm weather.

Fruit damage is done early, usually by the time fruit is one-third grown. Both adults and larvae are responsible but the larvae, feeding in small groups, do the most damage; in summer they concentrate on tender tips of canes and unfolding leaves, doing almost no feeding on berries.

Grape thrips occur in most of the grape-growing regions north of the Tehachapi mountains. Heavier infestations occur in sandy soils and in dry seasons. All varieties of grapes are attacked, but white varieties are preferred. When infestation is severe the tips of the canes may be stunted or killed, and all new leaves put out on the pheriphery of the vine after June are curled and present a scorched appearance. If grapes are sent to the winery, the scarring of the berry skin is of little importance.

Not all thrips found on grapes are harmful. Some are beneficial species predatory on spider mite pests.

Control: chemical. From the time buds begin to swell until warm weather forces rapid growth of the shoots, the vines must be watched closely for several pests including cutworms and other lepidopterous larvae, bud beetles, grape thrips, grass thrips, etc. When presence of grape thrips appear to be potentially injurious, the grower must be able to apply chemical controls quickly if they are needed.

Scales insects are rarely of economic importance in California. Many of them have been found living on grapevines, however, and control measures are occasionally necessary.

These scales may be separated into two groups—those that may feed in more than one part of the vine and those that remain stationary after selecting a place to feed.

All scale insects of the first group secrete a sugary liquid excrement. (Other grape pests that produce a sugary excrement are mealybugs and whiteflies.) When mature, scales in this group are $\frac{1}{5}$-inch long or more. The group includes the cottony cushion scale, soft brown scale, cottony maple scale, brown apricot scale, frosted scale, and black scale.

An individual of the second group feeds only in the spot on the vine where it first settles. These scales never become larger than $\frac{1}{10}$-inch in diameter. This group includes the oystershell scale, oleander scale, olive scale, California red scale, Florida red scale, greedy scale, grape scale, San Jose scale, and walnut scale.

Brown apricot scale

An example of the first group of scale insects is the brown apricot scale, *Lecanium corni* Bouche.

The adult females are brown, from $\frac{1}{8}$- to $\frac{3}{16}$-inch long, and nearly hemispherical in shape. They may be found on leaves or bunches, but mostly on stems of the current season's growth or on 1- to 3-year-old wood. Eggs are laid beneath the body, which gradually shrinks against the outer body wall to form an egg-filled pocket. As more eggs are laid, the body walls of the scale become hard and (after death) brittle. The winter is spent on 1- to 3-year-old wood as small immature stages. There is only one brood a year.

This scale produces a great deal of honeydew, which makes grapes sticky and sooty in the same manner as does honeydew produced by the grape mealybug.

Control. Control may be accomplished in the dormant season with mealybug sprays. Sprays applied to table grapes in summer may cause fruit spotting and loss of waxy bloom, especially in late summer.

Cottony maple scale

In California this scale, *Pulvinaria vitis* (Linn.), is found in the Lodi area, and only occasionally are control measures required. The females, which produce cottony egg sacs, are found on canes produced the previous season. As the scale continues to lay eggs, the sac is enlarged. Each female lays about 3,000 eggs. The sacs remain for some time after the fe-

Brown apricot scale on a twig. (Photo by H. Kido.)

male dies and the larvae have crawled to the undersides of leaves.

The immature yellowish or greenish scales feed by inserting their long thin mouthparts into the living plant tissue and sucking up the juices. Their sugary liquid excrement, falling on the leaves below the scale colony, makes the leaves and fruit look wet and shiny. The excrement also supports growth of a black sooty fungus which makes the bunches unattractive. This excrement is attractive to ants which feed on it and ants (and shiny or sooty leaves) are frequently noticed before the scale insects themselves are seen.

In late July and early August the males develop into minute, winged adults. After mating, the wingless females crawl back to young canes where they spend the winter. At this time they are about 1/7- to 1/6-inch long, flat and oval in outline and brown-colored. These scales attain a maximum length of about 1/5 inch in May. Where backyard vines have not been sprayed in the winter, females and their egg sacs may be dislodged by a strong stream of water early in spring. Otherwise, control is the same as brown apricot scale on grapes.

Grape scale

The grape scale, *Diaspidiotus uvae* (Comstock), is an example of the second group of scale insects. It gives vines a dirty-white appearance when infestation is heavy. Any place on trunk, arms, or canes where scales can reach living tissue with their sucking mouthparts may be infested. Most of the scales are found on the 2-year-old canes—when scales are abundant, they may severly stunt growth.

Each female produces 35 to 50 living young which crawl under loose bark of the previous season's growth and settle mostly in rows. After settling, this scale feeds on no other spot on the vine. The winter is passed in a half-grown condition.

Control. For grape scale and other scales that infest vines, control is best obtained by winter sprays. Dormant sprays for control of grape mealybug will also control scale insects. Loose bark should be removed before spraying whenever practical, and thorough spraying is essential. Because most of the scales overwinter on younger wood, severe pruning will be most helpful in reducing scale population.

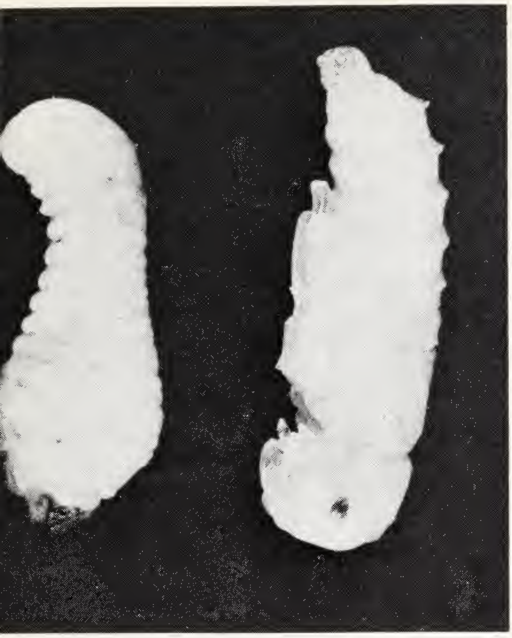
BRANCH AND TWIG BORER

When numerous these beetles, *Polycaon confertus* Le Conte, have killed more than half of all the new shoots in some vineyards.

Appearance. Females are brown or blackish, cylindrical, and about 2/3-inch long. Males are smaller, about 1/3-inch long, and are frequently found in attendance while the female feeds.

Development. The eggs, which are cylindrical and slightly pointed at one end, are laid singly in cracks and crevices in rough bark on the arms or occasionally

Adult branch and twig borer. (Photo by H. Kido.)



Branch and twig borer pupa, left, and larva, right. (Photo by H. Kido.)

on the trunk. The white wood-boring larvae that emerge have three pairs of stubby legs near the brown head. The body is enlarged near the head end.

Once established in the trunk or arms of a vine, the grubs feed for nearly a year and when full-grown, usually in April, they burrow to a position near the tip of the arm where they prepare a hollow cell in which to pupate. After a week or two in the pupal stage the adults emerge.

Injury. In spring when new shoots are 8 or 10 inches long they may wilt or break off in a wind storm and hang down, attached to the spur. Close inspection of such wilted shoots may show a hole bored in the crotch formed by the shoot and the spur. This hole represents a feeding puncture made by the adult of the branch and twig borer. Careful examination of the vines at this time will reveal the beetles engaged in this type of feeding. The feeding puncture is often deep enough to contain the entire beetle, or the tip of the body may protrude from the hole.

The larvae do equal damage, boring into wood in dead or dying areas. Once established, however, they feed with equal ease on both living and dead wood. As they progress slowly through the wood they plug the burrow behind them with frass (excrement) and chewed wood. This material looks like fine, tightly packed sawdust. As many as 20 grubs may be found in a single arm.

Control. No method of killing these pests with chemicals has been devised because cultural control methods are entirely satisfactory. Because the newly-hatched grubs enter the vine through dead and dying areas on trunk and arms, they can be controlled in part by keeping the vines healthy and pruning out all dying and dead parts.

Damage by this pest can best be prevented by burning all infested wood in winter. Experience has shown that severe damage to vines usually occurs in the vicinity of wood or brush piles. These insects feed in the wood of many orchard trees and ornamental trees and shrubs, including accacia, almond, apple, apricot, currant, fig, grape, manzanita, oak, olive, peach, prune, and others. Consequently, such wood—especially infested wood from grapevines—should not be piled beside the vineyard. All such wood should be burned before March, while the pest is still in grub stage.

TERMITES

The grape grower is especially aware of termites because he must drive wooden stakes into the ground to support young vines, or must erect braced posts to sup-

port a wire trellis. However, the damage done to living grapevines may go unnoticed until an arm or a whole vine is weakened by termite feeding. The species that attacks the vines is called the subterranean termite, *Reticulitermes hesperus* Banks. There are several other species in northern California, but they have not been found in vines.

Appearance. The adult sexual forms, seen during swarming, are black with two pairs of long slender wings. They are frequently believed to be flying ants, but can easily be distinguished from ants by their broad waists (ants have a slender, threadlike waist).

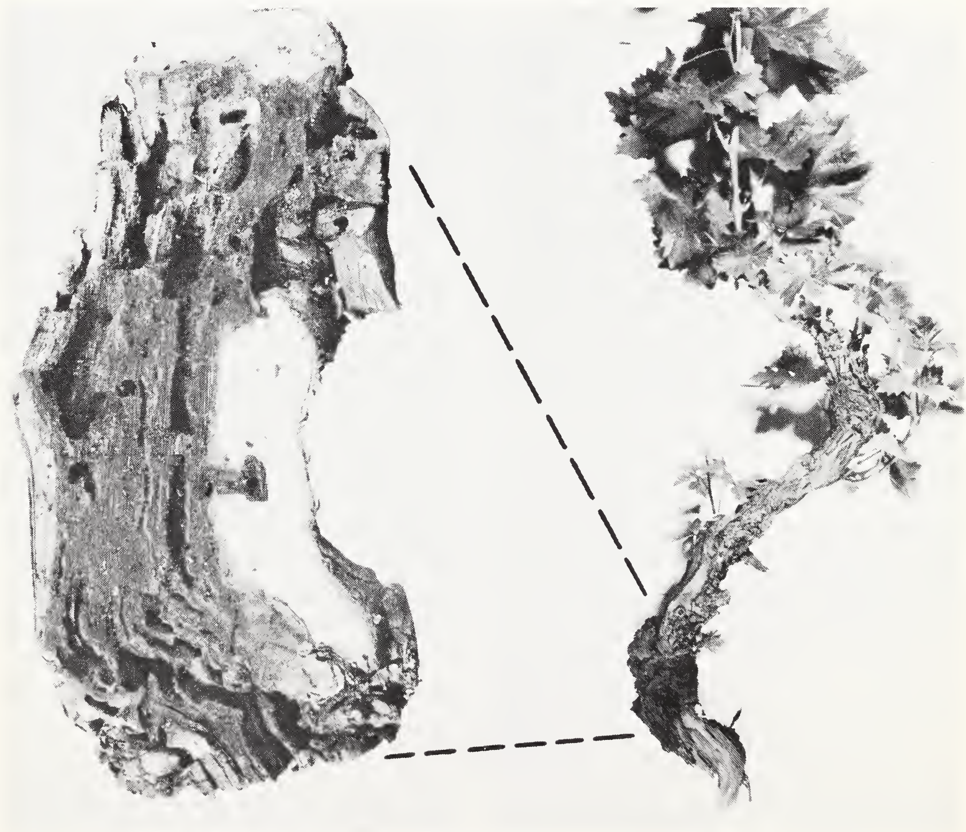
Development. The subterranean termite swarms after the first fall rains. Swarming is the mating flight of the winged sexual forms.

After a short flight, the males and females associate in pairs on the ground and break off their wings. Each pair becomes king and queen of the new colony that they intend to establish. They excavate a small hole in the ground and raise a brood of wingless workers.

As soon as the workers are able, they seek edible wood in the vicinity of their nest. Wounds exposing the heartwood, old beetle holes, or decayed pruning saw cuts are necessary for entry of termites into the vines.

Injury. In their attack on the vine, ter-

Termite damage to grape wood. Note that new growth on the arm at the right is nearly normal. At left is a longitudinal section of the marked portion of the arm showing the extent of the termite invasion and the small amount of white living wood. (Photos by H. Kido.)



mites eat the heartwood and avoid the living sapwood. Termites will live for years in heartwood core and only slightly penetrate the outer, surrounding sapwood. Usually the entire core of the wood is honeycombed, and its structural strength so weakened that breakage occurs with the least unusual strain.

Old vines show more termite damage than do young ones. In some districts vineyards 40 years old and older are 100 per cent infested with termites. They have had much greater opportunity to become infested, and in old vines the protective sapwood becomes much thinner. Surface injuries and heavy saw cuts then expose more of the acceptable heartwood for possible termite invasion.

Control. Control of termites is a matter of prevention. Care should be taken to avoid scarring the vines with cultivating tools. Saw cuts 12 inches or more above the ground are probably rarely a point of entry, unless the heartwood is softened by wood-rot fungi or reduced by branch and twig borers, in which case the king and queen may establish their nest there as though it were soil.

Stakes are normally heartwood of redwood, but, when possible, may be made from discarded cedar telephone poles—heartwood of cedar is quite resistant to termites. When non-resistant woods must be used, they should be treated with chemicals to protect them against termite and wood-rot fungi.

CICADAS

Cicadas are well-known because of the loud clicking or buzzing noises they make on warm summer afternoons. Although everyone has heard them, few have seen them despite their large size. When approached, they dodge around a limb and always stand on the opposite side from the observer.

One of the smaller species, called the minor cicada, *Platypedia minor* Uhler, occasionally injures grapes.

Appearance. Adults of the minor cicada are about ¾-inch long with black or bronze-black bodies and two pairs of large, colorless, transparent wings. They produce a loud clicking noise that sounds like two glass marbles struck together rapidly.

Development. Egg-laying activities begin late in April when adults emerge. The females are provided with a strong saw-toothed rod on the hind end of the abdomen with which they can drill holes into the hardest wood. They drill holes into grape canes to prepare niches to hold their eggs. After a hole has been cut, the female lays four or five eggs in it, then moves forward about a quarter of an inch and repeats the performance, until a row of five to ten such punctures results.

The eggs hatch in a week or two, and the young make their way to the ground and burrow in. The front legs of the young cicadas are greatly enlarged for digging in the soil. They may burrow to depths of 3 or 4 feet, where they feed on roots.

From 2 to 3 years are spent below ground before the young are fully grown and ready to transform to the winged adult. The young cicada then leaves the soil and crawls up a few inches on grass, fence posts, etc., the skin splits down the back, and the adult emerges, leaving its old skin intact and firmly attached to its support.

Injury. The damage of the minor cicada is caused by females as they carry out their egg-laying activities. Each puncture of the grape cane is made conspicuous by slivers of wood protruding from it.

Whether or not the young, during

their life underground, feed on grape roots has not been proved. It is known that they feed on French prune roots, and it is also known that when prunes and grapes are both available the females prefer to lay their eggs in grapes. This would indicate that young cicadas probably do feed on the roots of the vine.

Control. Control of this pest is achieved by normal cultivation. When young cicadas are fully grown they make their way upward during February to positions an inch or two below the surface of the soil. Disking the soil before the emergence of the adults during the last 2 weeks of April crushes many of them, and appears to interfere otherwise with their emergence. Pruning canes to a short spur in the winter, and thereby removing many visible egg punctures, is of no value in control of this pest because the eggs have long since hatched. If cultural control has been neglected it may be necessary to resort to chemical control. This insect appears to be tolerant to many of the available insecticides.

DARKLING GROUND BEETLE

Darkling ground beetles (several species of the genus *Blapstinus*) damage young vines by feeding on wounds on the trunk occasionally made by cultivating tools.

Darkling ground beetles, about 9 times normal size. (Photo by H. Kido.)

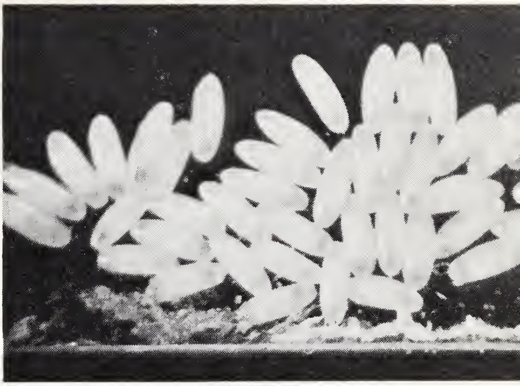
They may start to feed on the fresh, succulent tissue exposed by a recent cut, or if the wound has started to heal they will feed on the callous tissue. In either case, they extend the wound slowly around the trunk and to a lesser extent up and down the trunk, feeding through to the wood cylinder and eventually girdling the vine. Such girdles are often 2 to 3 inches wide.

The larvae live in the soil and are called false wireworms. They feed on the roots of grasses and occasionally damage truck crops. The larvae do no damage to vines, however, since they prefer to remain in the upper, dry, 2 to 3 inches of soil and do not penetrate to the depth of the vine roots. It is only in the adult stage that they damage the vine.

Control consists of dusting an insecticide liberally over a circular area of soil extending about 3 feet from the vine.

GRAPE BUD BEETLE

The grape bud beetle, *Glyptoscelis squamulata* Crotch, is found on grapes in parts of Fresno County and near Lodi. Normally it feeds on various weeds in these areas. In the Sacramento Valley it is commonly found on poplar and willow. In Fresno County adults have been found on the callous tissue of grafts on plums.

Left: Grape bud beetle, about 6 times natural size. Right: Egg mass of grape bud beetle laid by one female. (Photos by H. Kido.)

Grape bud beetles may be numerous in the vineyard and still remain invisible to the grower because, like cutworms, they conduct their feeding operations at night and conceal themselves during the day. From observations of the damage alone, it is difficult to decide which pest is responsible. If, a grower wishes to satisfy his curiosity, he should examine the vineyard with a flashlight after dark on a warm spring evening.

Appearance. The beetles are light-gray, hard-shelled insects about ¼-inch long. Only a few beetles feed on the buds at one time, the great majority remaining hidden under the bark of the vine. Consequently, if very few beetles are seen, it should not be concluded that the infestation is so slight as to be of no economic importance.

Development. The female lays eggs in spring in compact masses of 20 to 30 eggs each and conceals them in the deepest cracks in the grape bark. In a few days, the eggs hatch and the young larvae crawl or fall to the ground and immediately burrow into it. They then seek the roots of the vine and feed on them, without, however, producing noticeable loss of vitality in the vine. The larvae may go to a depth of 2 or 3 feet in quest of roots. They remain in the soil all summer and all winter. In early spring the larva constructs a smooth cell in the soil, and in it transforms to the pupal stage from which the adult beetle later emerges.

Injury. Like the cutworm, grape bud beetles feed on opening buds during spring nights. As dawn approaches they crawl down and hide in the rubble on the ground, or under loose bark on the trunk and arms of the vine. They feed on swollen or opening buds, usually starting at the tip of the bud and gouging out the heart, leaving the bud scales nearly intact. Close inspection is therefore necessary to discover the hollow, dead buds. After the new shoots are 1 or 2 inches long, the injured buds are conspicuous by their lack of growth. Occasionally, one or both side-growing points of the bud are not injured and may produce canes that are apt to be unfruitful.

Control. Dusts or sprays have been used successfully. Applications should be made to the stakes as well as the trunks and arms of the vine. The purpose is to cover with insecticide all paths by which the beetles will walk from their hiding places to the opening buds.

CUTWORMS

Damage to buds by cutworms in the early spring coincides with similar damage by bud beetles and click beetles. The click beetle may be easily observed, as it feeds on buds in full daylight. The cutworm and bud beetle are more insidious, hiding during the day and emerging after dark to do their feeding.

Cutworms are larvae of moths that fly at night and hide during the day. Though many different species attack grapes, the three common ones are the variegated cutworm, *Peridroma saucia* (Hubner), the greasy cutworm, *Agrotis ypsilon* (Rothemburg), and the brassy cutworm, *Orthodes rufula* (Grote). Of these three, the variegated cutworm is the one most often found. The spotted cutworm, *Amathes C-nigrum* (Linnaeus), was found widely in 1971.

Appearance. Cutworms are dull-colored and characteristically marked with faint spots or lines. Their smooth bodies are 1½ inches long when fully grown.

The color of the variegated cutworm varies from ashy gray to brown, with a light mottling of darker brown. Down the backs of the larvae there is a pale yellow dot in the middle of most of the segments. The moths have grayish-brown forewings measuring from 1½ to 2 inches when spread. The hind wings are clear except for darker margins. Larvae of the greasy cutworm are dull brown to nearly black. There is a broken light line down the middle of the back and a faint light line on each side. Larvae appear greasy in texture. The moths are a dull, mottled brown, darker than the variegated cutworm moths.

Other species are much the same size in larval and adult forms. The moths are generally dull brown or blackish.

Development. Cutworms that attack grapes spend the winter in vineyards as partially-grown larvae in the soil. When temperatures become warm enough in spring, the larvae emerge at night to feed on many kinds of succulent plant material, including buds and young shoots of the grapevine. A succeeding generation of larvae become full-grown in late spring.

Variegated cutworm larva. (Photo by H. Kido.)

Greasy cutworm larva. (Photo by H. Kido)

The variegated cutworm moth lays its eggs in batches of 60 or more on leaves and stems, on twigs and branches of trees, or on fences and buildings. The eggs are small, round, and flattened, and are laid in rows. Many other species of cutworms prefer to lay their eggs on the stems of grasses near the ground.

Grass and other weeds in the vineyard furnish food for cutworm larvae, as well as favored locations for the moths to lay their eggs. Vineyards having a heavy crop of grasses in the fall are more apt to have cutworms the following spring than vineyards that are clean cultivated.

On hatching, the young feed on low-growing vegetation. By the time the first brood has hatched, the grapevines have so much foliage and are growing so vigorously that the cutworms generally do but little damage the rest of the season.

Injury. Cutworm damage to vines occurs from the time the buds begin to swell until the shoots are several inches long. In the daytime the larvae hide themselves in loose bark or soil at the base of the vines and are hard to find. At night they climb the vines and feed into the buds and succulent shoots from one side. Shoots are often eaten only partway through so that they are weakened and fall over. This habit of partially cutting off the succulent stems of many different kinds of plants gives the cutworms their name. If there is not enough food near the ground, some climb vines and trees to feed and thus become known as climbing cutworms—this may occur if vineyards are disked at the time buds are swelling.

Control. Cultural practices have not been generally successful in controlling cutworms. Plowing under the grass in the fall is of some value because it exposes some of the insects to the weather and to predators. Poison baits may be spread near the trunks of the vines late in the day. Though it may be easier and perhaps somewhat more effective to use insecticidal dusts or sprays to control cutworms, the use of baits will be less likely to upset the balance of natural enemies of grape insect and spider mite pests. Although a dust or spray application in early spring may not be costly and therefore may be considered as cheap insurance against cutworms, such insurance may be costly if it upsets the biological control of some other pest.

Applications should be made just before buds start to swell in spring, or as soon as feeding damage is observed. If a dust is used, rain may make a second application necessary. To determine the effectiveness of chemical control, one should visit the vineyard early in the morning the day after the application is made—soon after sunrise birds usually eat most of the cutworms killed by applications of insecticides.

CLICK BEETLE

Click beetles are better known throughout California as "wireworms" because the immature or larval stage is a wireworm. Wireworms are common in vineyard soils but apparently feed mostly on roots of weeds and cover crops. However, the adult (click beetle) is often a serious pest in vineyards.

Click beetles are easily recognized by a characteristic action and sound. If one of these long, slender, hard-shelled beetles is held between the thumb and finger, it will arch its body backwards, then straighten out with an audible snap.

Of the hundreds of species of wireworms in California, only the Pacific Coast wireworm, *Limonius canus* Le Conte, is regularly injurious to grape

Click beetle destroying bud on a spur. (Photo by H. Kido.)

buds. Other species are frequently found in vineyards, but they emerge too late in the spring to damage the opening buds. In spite of its name, it confines its attack to the interior valleys and is probably absent in the actual coastal belt.

Appearance. Female adults may attain a length of ½ inch, males a length of about ⅜ inch. Females have reddish-brown wing covers, and the head and thorax are dull brown. Males lack the distinct reddish tinge in wing covers and appear dull grayish brown.

Development. Adults of the Pacific Coast wireworm hibernate in winter under rubble on the ground and emerge to feed on warm days in March. They are often found in various flowers.

The click beetle lays its eggs in the soil. In 2 or 3 weeks they hatch into minute wireworms. The larvae, or wireworms, are well named since the long, slender, hard, polished body suggests a piece of wire. When the wireworm is fully grown it constructs a cell in the soil and therein transforms to the adult, or click beetle.

Injury. Damage to buds in early spring by the click beetle is difficult to distinguish from that done by bud beetles. Unlike the cutworm and bud beetle, however, click beetles may be seen feeding at the apex of the buds in full daylight. Since they have wings and fly readily, they reach the spurs by flying instead of walking as do the cutworms and grape bud beetles. Their flight activity is particularly noticeable in late afternoon on warm days.

Control. This insect may be controlled at the same time as the cutworms and bud beetles are controlled. Click beetles seldom occur in sufficient numbers to warrant chemical control measures, but when their damage is added to that of cutworms or bud beetles, total bud injury may result in severe crop loss.

LITTLE BEAR BEETLE

Although the little bear beetle, *Pocalta ursina* (Horn), is widely distributed throughout California, it has been a pest of grapes only in the southern San Joaquin Valley, where climatic and other factors are especially favorable for its development.

Appearance. The little bear beetle is one of the largest insects that attack grapes. Adult beetles have broad, thick, hard bodies and vary from ½ to nearly 1 inch in length. The wing covers of most of them are dark reddish-brown, but in a few may be black or light-brown. The

head and thorax are black, and in certain lights will give a suggestion of purple sheen.

Development. The females lay their eggs in the soil, and the white, six-legged grubs spend their entire time in the soil, probably feeding on the roots of grasses.

Injury. In the southern San Joaquin Valley the adults occasionally attack the young, tender shoots in late March and April. No case of injury by the soil-living grubs to the roots of grapevines has been discovered.

Control. Application of pesticides should be delayed until damage from the pest reaches economic proportions.

FLEA BEETLE

The flea beetle is so named because it can jump like a flea. Several different species are known to attack grapes in different parts of the country, but in California the steel-blue grapevine flea beetle, *Altica torquata* Le Conte, is the only species of importance.

Appearance. The adult beetles are shiny metallic blue or purple, about $\frac{3}{16}$-inch long.

Development. Adults overwinter in surface debris and become active in the spring when grape buds are swelling and opening. After feeding for a few days they lay small light-brown eggs in cracks in the bark or the base of buds. The eggs hatch at the time new leaves are expanding. The newly-emerged larva feeds on the upper surface of the expanding leaves for 3 to 4 weeks, eating out irregular holes in the leaves. When fully grown the larvae are about $\frac{1}{3}$-inch long, and are yellowish-brown with black markings. When mature, the larva drops to the ground and penetrates to a depth of about 1 inch to form a cell in which to transform to the adult beetle. A week or two later the adult beetles emerge from the soil. During the rest of the summer they feed sparingly. There is only one generation each year.

Injury. Upon emerging from hibernation in spring, the adults attack swelling and opening grape buds and may completely destroy them. This pest, if unusually abundant, may destroy all the buds in a vineyard, but usually only part of the vineyard is attacked.

ROOT-KNOT NEMATODE

Nematodes are spread chiefly by man accidentally transporting them. Infested rootings used in planting new vineyards are perhaps the single most efficient means by which nematodes are spread. They are also readily carried by water for considerable distances, and they are also spread in the vineyard by cultivating tools. Young worms may remain in the root where they hatch and work their way along through the root tissue, but they may also move actively through the soil to reach and enter other roots, though their own movement is extremely slow. (It is estimated that a nematode might travel $1\frac{1}{2}$ feet in 24 hours if it kept to a straight course.)

Soil type, therefore, plays an important part in the severity of nematode infestations. Porous, sandy, or loam soils especially favor the increase and spread of

this pest, whereas infestations in heavy soils are less serious.

Under favorable soil, moisture, and temperature conditions, the root-knot nematodes, *Meloidogyne incognita, M. javanica* and *M. thamesi* cause a decided weakening of growth and a decrease in production.

Appearance. In their young stages these pests are microscopic and worm-shaped. As the young worms grow and mature, the males remain wormlike but the females become pear-shaped.

Development. Eggs are laid in root tissue or knot, a single female laying 500 or more eggs. Development of the root-knot nematode has no seasonal limits but progresses slowly or rapidly depending on temperature. The most rapid development occurs at about 80°F. At this temperature the eggs hatch in about 8 days and the young worms develop into egg-laying females in the next 16 to 18 days. Thus a generation may be completed within about 25 days and many generations are possible each year. At lower temperatures the development is slower: at about 58°F a complete generation may require 100 days or more.

Injury. Abnormal growth takes place when the roots are infested, causing characteristic swellings (knots or galls). Such swellings usually cause enlargement of the whole root, whereas swellings caused by phylloxera occur mostly on one side of the root, or consist of hook-shaped galls at the tips of small rootlets.

Leguminous plants such as clover and vetch which may be uprooted in the vineyard will have small root galls caused by beneficial nitrogen-fixing bacteria. Such galls are only loosely attached to the roots and are easily rubbed off, whereas nematode galls cannot be rubbed off. Root-host nematodes frequently give rise to a series of knots on the same root, somewhat resembling a string of beads.

Control. Long-term control of root-knot nematodes on grapes by postplant or side-dressing chemical treatments of established vines is not generally successful. Large numbers of the nematode usually build up again within months after a postplant treatment, often to larger numbers than the original population. Repeated applications will not eliminate the root-knot nematodes from a vineyard but will give some benefit to young vines, although not enough to become economically practicable.

Preplant treatments of soil with certain soil fumigants have given sufficient control of the root-knot nematode to allow establishment of a vineyard. The nematodes start to build up soon after the vines are planted, and after one or two years of growth additional control measures are needed.

In heavily infested sandy soil the use of resistant rootstocks is the most effective means of control of root-host nematodes. Technically speaking, the rootstocks are tolerant rather than resistant (i.e., the nematodes can actually develop on the roots). Generally, the term "resistant rootstock" is used in connection with the performance of the vine (yield and quality) as compared to the performance of a vine on its own roots in an infested area. The Solonis x Othello 1613 stock is suggested for fertile, irrigated sandy loam soils with all varieties except Ribier. Salt Creek is suggested for coarse sandy soils that may be low in fertility and for Ribier wherever nematode-resistant stock is required. Fruit produced by vines on nematode-resistant stocks is usually somewhat inferior in quality to that produced by own-rooted vines in noninfested soils. Growers are cautioned therefore to use grafted vines only when there is good reason to believe that they are required. Usually the areas requiring nematode-resistant vines are small and may not include the entire vineyard.

All American varieties of grapes and hybrids are believed to be susceptible

to root-knot nematode attack. The grape species *Vitis doaniana, V. champini, V. longii,* and *V. cinerea* show tolerance to these nematodes. Salt Creek (*V. doaniana*), Dog Ridge (*V. champini*), and the two *V. longii* hybrids, Solanis x Othello 1613 and Solonis x *V. riparia* 1616, have shown tolerance to root-knot nematodes.

ROOT-LESION NEMATODE

The root-lesion nematode, *Pratylenchus vulnus* Allen and Jensen, may also cause stunting, poor growth of vines, and lowered yields. Both young and adult worms can be found in the roots and in the soil around infested plants. In contrast to the root-knot nematode, the root-lesion nematode does not cause the formation of galls on the roots, nor do the females become swollen and sac-like. Males and females are elongate worms and are able to penetrate into roots in both the larval and adult stages.

These nematodes penetrate into small roots, and if the infestation is severe the roots are killed. Severely injured plants usually have a greatly reduced root system; lighter infestations may induce the production of numerous lateral rootlets. Rootstocks tolerant to root-knot nematodes do not appear to be tolerant to the root-lesion nematode, and no other sources of resistance are known at present. Soil fumigation procedures are essentially the same as for root-knot nematodes.

DAGGER NEMATODES

Two species of *Xiphinema* are known to attack grapes in California and are widely distributed. These are relatively large nematodes which are ectoparasitic, migratory types. They do not enter the roots but instead feed on young rootlets near the growing tips—this suppresses growth of young roots and the root tips often become swollen and curved or distorted. Feeding of large numbers of the dagger nematode may induce a dense mass of abnormally branched and swollen and darkened or necrotic rootlets.

One species, *Xiphinema index,* is the vector of the fanleaf, yellow mosaic, vein-banding virus disease complex of grapes. This nematode transmits these viruses to new plantings in old virus-infested vineyard soils even after several years' delay before replanting.

X. index is commonly found in the coastal areas and occurs in the San Joaquin Valley as far south as Visalia and Delano. *Xiphinema americanum* is the other species found very widely throughout California soils. It is associated with damage on a wide variety of crops.

CITRUS NEMATODE

Tylenchulus semipenetrans is a sedentary, semi-endoparasite found on grapes in southern California and the San Joaquin Valley.

The young larvae of this species feed on outer cortical layers of young roots. As females develop through successive larval stages, the head penetrates deep into the rootlet while the body remains outside the root, enlarges, and becomes a variably-shaped swollen structure on the surface of the root.

OTHER NEMATODES FOUND IN GRAPE SOILS

There are several other groups of nematodes found in vineyard soils whose life habits and pathogenic effects have not been completely investigated. Although they occur on roots and in the soil around roots in large numbers, their effects on most plants are still not known. The spiral nematodes include members of *Rotylenchus* and *Helicotylenchus*. Recently, it was found that *Helicotylenchus dihystera* is an endoparasite of grapes inside the grape root cortex. Ring nematodes, *Criconemoides* spp., and pin nematodes, *Paratylenchus* spp., are some of the many ectoparasitic migratory types which are widely distributed in vineyard soils in California.

Preplant soil fumigation procedures for dagger nematodes, citrus nematode, and other ectoparasitic species mentioned above are essentially the same as for root-knot nematode. However, growth responses following side-dressing treatments using certain soil fumigants have been economically successful in many vineyards where such ectoparasitic species are present. This is especially true for infestations of the dagger nematodes.

GRAPE PHYLLOXERA

Although the grape phylloxera, *Dactylosphaera vitifoliae* Shimer, is native to the U. S. and has lived here many thousands of years on native wild grapes, it did not occur west of the Rocky Mountains until discovered in California in 1852.

From its inception, phylloxera spread quickly. It is now quite generally distributed throughout northern California. A few counties in the San Joaquin Valley are believed to have none. California is especially fortunate in that the winged migratory forms do not succeed here as they do in the eastern states and in Europe. Unaided spread of the pest is therefore limited to the distance the wingless crawlers can cover, and they can travel only a few feet. During late summer and fall occasional winged phylloxera appear in coastal areas. They emerge from the soil and fly about, but unlike the eastern forms they are unable to establish new colonies.

Appearance. These minute, oval or pear-shaped insects are best recognized by the damage they do, since their entire life is spent on the roots of the vine. Microscopic in size, the adult phylloxera is yellowish-green or yellowish-brown.

Development. The adult female remains practically stationary on the root of the vine and her eggs pile up around her. As the young hatch, many settle on the root close to the female and begin feeding. Others show wandering tendencies. They crawl upward through cracks in the soil, travel a short distance on the surface, then enter cracks, crawl down the roots of another vine, and establish new colonies.

There are usually five generations each season, but in exceptional cases eight have been counted.

Injury. The combined feeding of the adult females and young on the root of the vines causes gall formation. On new rootlets the galls are hook-shaped, on older roots they are half-spherical swellings. After a month or two the galls begin to decay, and the phylloxera then move to another place on the root and produce new galls. It is believed that the decaying galls and a poisonous saliva injected into the vine by the phylloxera are responsible

Colony of adult females, eggs, and crawlers of grape phylloxera on grape root. (Photo by H. Kido.)

Phylloxera (arrow) on rootlet. Note typical deformity of rootlets caused by feeding. (Photo by A. Marin.)

for the stunting and decline of the vine. Root killing—especially the destruction of fine feeder roots—is of course partly responsible for loss of vigor.

Soil type plays an important role in phylloxera infestations. In order to prosper the phylloxera requires a soil that will contract and crack when drying. Such a soil shrinks slightly away from the roots, thereby providing open passageways so the phylloxera may crawl along the roots to infest the whole root system. Also, cracks in the soil are the only means by which these aphids can leave an infested vine and reach the roots of an uninfested one.

In the San Joaquin Valley the soils of heavier texture of the Madera and San Joaquin series are favorable to general phylloxera infestation, as are the adobe soils of the Porterville series. Sandy loams of the Hanford and Foster series are less favorable, while Madera and Oakley sands and Fresno sand loams are practically immune to phylloxera infestation. In general, soils so sandy that they will not crack when dried after a thorough wetting will probably be immune.

Control. Control of phylloxera is largely a matter of prevention. The roots of American varieties of grapes have varying degrees of resistance to phylloxera. Numerous hybrids of American varieties possessing a high degree of resistance have been produced, and these rootstocks should be used in situations where phylloxera presents a real threat. Technically, these rootstocks are tolerant.

Rupestris St. George is the standard phylloxera-resistant stock for wine-grape varieties on the nonirrigated soils in the coastal valleys of California where it is recommended and used almost exclusively. On the more fertile irrigated valley floors of this district the hybrid stock, AYR No. 1, has given good performance.

Solonis x Othello 1613 is moderately resistant to phylloxera. It is sufficiently resistant to be used in the fertile, irrigated, sandy-loam soils in the San Joaquin Valley where nematodes are also a problem as it is quite resistant to root-knot nematodes as well. It is not known to be incompatible with any variety except perhaps Ribier. In nonirrigated soils and in very poor sandy soils the

grafted vines are likely to be weak and unproductive.

Growers should guard against the accidental introduction of phylloxera into their vineyards. This pest may be spread by grape rootings and bench grafts that were grown in infested soil; by irrigation or drainage water flowing out of an infested area; by cuttings contaminated with infested soil; by old vines removed from infested vineyards; by tillage tools, especially disks and plows that tend to collect masses of soil; and by tractors and trucks, especially when the soil is muddy. Nursery stock can be completely freed from phylloxera and made safe for planting in uninfested soil by fumigation after first washing all soil from the vines and roots. The dipping of washed grape rooting into emulsions of several insecticides has been reported to effectively control phylloxera.

WESTERN GRAPE ROOTWORM

In recent years the western grape rootworm, *Adoxus obscurus* (Linn.), has been of minor importance in California, but about 40 years ago it was a serious pest. It is still present in most vineyards but has become so scarce that it does only negligible damage. In the grub, or larval, stage it feeds on roots of the vine. The insect's life history suggests that its gradual disappearance may be due to the use of the disk rather than the moldboard plow for cultivation.

Appearance. Like the bud beetle, this little (about 1/5-inch long) pest is seldom seen because it is nocturnal. It is recognizable chiefly by the obvious damage the adult does to vine leaves.

Development. Adult beetles emerge from the soil in May and feed for about 2 weeks on leaves in the lower part of the vine. The female selects a narrow crevice in the bark and wedges her eggs into this crack in groups of 20 to 30. The pale-yellow eggs hatch in about 2 weeks and the young larvae make their way to the soil, burrow in, and seek out the roots of the vine. Here they remain from June to April of the next year.

By fall the larvae are full-grown and are recognizable as white grubs about 1/3-inch long with a brown head and three pairs of short legs near the head. The body is curved into a C shape. As winter approaches they burrow down in the soil to a depth of 2 feet or more, where they spend the winter. In the spring they burrow upward to within a few inches of the surface, and here they construct a smooth-walled oval cell in which to pupate. Disking at this time may crush many that are in the pupal stage; the larval stage is much tougher and not easily crushed.

Adults of western grape rootworm and typical feeding cuts in leaf. (Photo by H. Kido.)

Western grape rootworm in typical feeding cuts in berries. (Photo by H. Kido.)

Injury. Slitlike holes in the leaves indicate the presence of the western grape rootworm. While feeding, adult beetles stand on the upper surface of the leaf and cut slits about $\frac{1}{20}$-inch wide and of various lengths, often $\frac{1}{4}$- to $\frac{1}{2}$-inch long. In severe infestations leaves are so completely eaten that they appear lacelike, and the vine may be completely defoliated; in such cases the beetles also feed on the green bark of canes and cut shallow grooves in the berries. Berries that have been thus nipped become misshapen and cracked.

During the larval stage in the soil this pest may eat small rootlets completely, but if roots are the size of lead pencil or larger the rootworm gouges holes through the bark and outer wood. Often the larvae feed along the length of a root, leaving behind them a channel filled with frass and chewed wood. If the feeding channel happens to spiral around a root, it will will be girdled and die.

Control. If chemical control is needed the application should be made as soon as the holes become numerous in the leaves, and that should be just before or just after blooming.

GROUND MEALYBUG

The ground mealybug, *Rhizoecus falcifer* Kunkell, is a minor pest of grapes. It has not been found in commercial vineyards and is only occasionally injurious to backyard vines in the coastal areas. It is found mostly along the coast from San Diego to Mendocino County, feeding on many plants including grasses, broad-leafed annuals, cacti, citrus, deciduous fruit trees, and ornamental shrubs. This pest lives entirely in the soil, feeding on the small roots of the vine. Superficially, it does not look like a mealybug because of its smaller size, long slender body, and absence of wax rods and filaments that characterize other mealybugs. Its body is covered uniformly with white waxy powder.

Chemical control of the species has

Adult ground mealybug in soil. (Photo by H. Kido.)

never been necessary in commercial vineyards, and since it occurs rarely on backyard vines no chemical control method has been devised.

RAISIN MOTH

Although the raisin moth, *Cadra figulilella* Gregson, is known to feed on ripening grapes on the vine it is chiefly a pest of raisins in storage, especially in farm storage before the raisins are delivered to the packing houses.

Appearance. The raisin moth is about the same size and shape as the Indian-meal moth, and folds its wings around its body in the same manner when at rest. It can, however, be easily distinguished by the drab gray of the forewings, and the markings on the wings are obscure. The hind wings are whitish. There is much less difference in intensity of color between the fore and hind wings of the raisin moth than there is between the fore and hind wings of the Indian-meal moth.

Development. The adult moth generally lays her eggs on raisins drying on the trays, but she may also lay them on raisins in storage. When the worm is full-grown, it leaves the storage in search of a suitable place to transform to the moth stage. Any tight, dry, dark place, such as under boards, paper, or stones, or in the soil, is suitable. When it has found a satisfactory place, the worm spins a silken cocoon. Full-grown worms pass the winter in their cocoons; they pupate and transform to the moth stage during April, May, and June, the great majority of the moths emerging in June. On warm evenings they begin to fly and lay eggs about half an hour after sunset, and they continue to fly for 3 or 4 hours. The moths live for about 15 days, and each female lays about 350 eggs. In summer a generation is completed in 45 days. There are three overlapping generations each year and in some years a small fourth generation.

Adult raisin moth, about 6 times natural size. (Photo by H. Kido.)

The new spring moths do not lay their eggs in raisin storages because the raisins have by this time become unsuitable to them. Instead, they fly about in search of newly-drying fruit, and at this season waste mullberry fruit on the ground is among the first foods available for the larvae. By June first-crop figs on the ground are infested, and soon afterwards fallen apricots, nectarines, peaches, prunes, and peach-pit piles become available for egg laying. By August ripening grapes on the vine—especially those showing bunch rot or a few prematurely raisined berries—become attractive to the egg-laying moths. Later, they turn their attention to raisins drying on trays.

Injury. The young larvae hatched from eggs laid on raisins in storage feed chiefly on the ridge crests of the rai-

sin, but they may also bore into the flesh to the seeds. They do not consume a raisin but move about, leaving behind them a mass of excreta and webbing. During its development, one worm damages about 20 Thompson Seedless or nine Muscat raisins. The larvae of the raisin moth can also feed on ripening grapes on the vine.

Control. This pest can be controlled by sanitary cultural practices as well as by fumigation. The raisin moth lays its eggs on the drying raisins at night but high temperatures the next day will kill the eggs unless they are shaded. When the time comes to roll raisins drying on the paper trays, the raisins should be prepared in biscuit rolls in the later part of the afternoon, after the hot sun has killed the eggs that were laid the previous evening and before the moths have a chance to lay more eggs (in other words, before about 7:00 p.m.). To protect the raisins from reinfestation, the rolls should be tight and should not contain too much fruit. Raisins in rolled trays should be boxed in the vineyard or immediately after the rolls are brought to the farmyard.

Late-maturing Muscat raisins dried on wooden trays so that they can be stacked if rain threatens are more exposed to attack by the raisin moth than are raisins dried on paper trays. Stacking of wooden trays protects moth eggs from the killing rays of the sun. However, when wooden trays are stacked, the raisins can be protected from the egg-laying moth by a cover of shade cloth thrown over the stack. Raisin cleaners driven by an electric motor have been found effective for removing infestation from Zante and Thompson Seedless raisins. About 90 per cent of the eggs and worms can be screened out if the screen is properly operated. The most economical procedure is to run the raisins from the paper trays over the cleaner into sweatboxes without intervening storage or extra handling.

Although the length of time that boxed raisins are stored on the farm is influenced by market conditions, prompt delivery to buyers is desirable because infestation increases on the farm during periods of favorable temperature. The degree of later reinfestation of raisins in storage in packing houses by the raisin moth is negligible. Covering the boxes with shade cloth keeps out much of the raisin moth infestation that would otherwise occur during farm storage.

Drying mulberry fruit is the first available food for the worms in early summer. If infested mulberry fruit under the tree is raked out into the sun and spread thinly, the heat will kill the worms and eggs. This practice, and the use of nonfruiting strain of mulberry for shade, will reduce the local intensity of raisin moths

INDIAN-MEAL MOTH

The Indian-meal moth, *Plodia interpunctella* (Hbn.), is a serious pest in stored raisins and in many other types of dried fruits and nuts. Although usually not as numerous as the raisin moth, this pest can be very destructive because, unlike the raisin moth, it continues to lay its eggs in cracks and crevices in sweatboxes and other containers. Upon hatching, the larvae may crawl through the cracks to the inside of the container. The pest readily enters houses and lays its eggs on exposed raisins in open packages on the pantry shelf. In such instances it is easisr to discard small infested lots than to attempt cleaning and fumigation.

Appearance. The Indian-meal moth is about ⅜-inch long. Its wingspread measures about ⅝ inch. When at rest the wings are folded around its body. The outer two thirds of the front wings are a

Adult Indian-meal moth, about 5 times natural size. (Photo by H. Kido.)

dark coppery brown; the other third, near the body, is cream-colored. The hind wings are grayish.

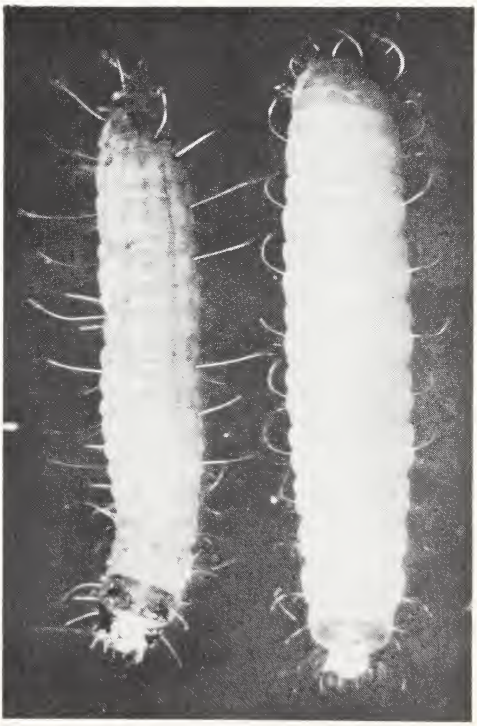
Development. The female moth lays approximately 300 gray-white eggs, which adhere loosely to the surface of the fruit and hatch in about 5 days. The worm, or larval, stage is completed in 30 to 40 days in summer. The full-grown larva spins a silken cocoon in which to pupate. The pupal stage lasts 5 to 10 days in summer. There are usually five generations each year. The pest passes the winter in the worm stage, either resting in cocoons or lying dormant in feeding tunnels in the dried fruit. Hiberating worms are able to survive the coldest winter temperatures out of doors in California. Transformation of overwintered worms begins in March and continues to the end of May.

Injury. Losses caused by the Indian-meal moth are due less to a reduction in quantity than to the lowering of quality, expense of extra handling and cleaning, and possible seizure and condemnation under the Federal Food and Drug Act, as well as possible rejection by the purchaser.

Infested raisins not only contain living worms but are also increasingly polluted by excrement, cast skin, webbing, dead worms, and silken cocoons. Their filthy appearance may cause a curtailment of the market by public discrimination against raisins.

Control. Control of this pest and other storage pests of raisins is accomplished primarily in the packing house. However, farmers holding raisins on the farm usually cover them with a gas-tight plastic or other gas-tight material and then fumigate them. As raisins are removed from storage, they undergo several processing steps before they are packaged and made ready for sale. Each step in the process-

Left: Larva of Indian-meal moth about 6 times natural size; Right: Larva of raisin moth, about 5 times natural size. (Photo by H. Kido.)



ing—sorting, cleaning, stemming, etc.—progressively reduces any infestation that may have been present. Raisins that have been fed on enough to make them lighter in weight are also automatically removed during processing.

At some step in the processing fumigation is applied. The raisins may be treated with an appropriate fumigant before packaging or, more commonly, a liquid fumigant may be added to the raisins as they are packaged. The liquid fumigant may be added to cartons containing smaller packages or placed in each package individually. Machine-sealed packages vary in their ability to exclude insects.

If any sizable amount of raisins is to be kept in home storage they may be placed in glass jars or other containers that can be closed with an air-tight seal. The raisins in the containers may be treated with a measured amount of dry ice and sealed after this material has vaporized completely and filled the container with carbon dioxide gas.

DRIED-FRUIT BEETLE

The dried-fruit beetle, *Carpophilus hemipterus* (Linn.), is widely distributed throughout the world. Apparently any material that can be fermented may serve as its food. Dried-fruit beetles are frequently found on figs—on trees or on the ground—in mushy citrus fruits, rotting apples, broken watermelons, etc. Thus, the chances are good that raisins will become infested whenever the conditions of storage are favorable.

Raisins moist enough for fermentation to start are especially susceptible. There is little infestation in the field if raisins are made from sound grapes. If the beetles do occur on grapes in the field, they are most likely to be found in late fall or winter; during this period they are most abundant in raisins.

Appearance. Adult beetles are dark brown with lighter brown or amber spots. They are about ⅛-inch long, oval in outline, and robust. The wing covers, which bear the lighter-brown spots, are short, leaving the abdomen exposed at the tip. The antennae are knobbed at the tips. Legs and antennae are reddish or amber.

These beetles are strong fliers—marked beetles have been collected 2½ miles from the point of release after 4 days. Flight occurs only in daylight hours at temperatures about 65°F. The greatest flight activity takes place at temperatures between 80° and 100°F.

Development. Each female lays about

Dried fruit beetle adult. (Photo courtesy of USDA Stored Products Lab., Fresno.)

Adults and larvae of the pineapple beetle, about 9 times natural size. (Photo courtesy of California State Department of Agriculture, Bureau of Entomology.)

1,000 eggs which are scattered over the raisins. The eggs hatch in 1 to 5 days (about 2 on the average) and the translucent yellowish larvae start to feed. The larvae soon become creamy white, brownish at both ends. They have a pair of pointed processes at the tip of the abdomen. When fully grown they are sparsely hairy and about ¼-inch long. The slender larvae are active and move about quickly. The larval period varies with the temperature, lasting 11 days at 80°F.

Whenever possible the full-grown larvae enter the soil and make earthen cells in which to pupate. The pupae are a pale yellow until nearly mature. At 80°F the pupal period is about 8 days. Mating takes place soon after adults emerge from the soil and eggs are laid from 1 to 8 days thereafter. Egg laying may start as early as 3 days after adults have emerged from the pupal cell.

During warm weather there may be a generation every 3 weeks. Actually there are several overlapping broods each year, the number of generations depending on the temperature. Larvae entering soil in autumn may not emerge as adults until spring because of low tempeartures.

Injury. The larvae feed directly on the flesh of raisins and this feeding, together with the excreta and cast skins, makes such a mess as to materially reduce the quality of the dried fruit. No feeding or development takes place below 40°F.

Control. Control of the pest is accomplished primarily in the packing house. Control measures are the same as those used for control of the Indian-meal moth.

In the last few years in certain other crops the major species is not *Carpophilis hemipterus* but *C. Frelmani*, *C. mutilatus*, and *Haptoncus leuteolus*. Perhaps these species will also become prevalent in grapes. Other related species that are pests of grapes and raisins are *Urophorus humeralis*, the pineapple beetle which is black and larger than *C. hemipterus*, and *C. dimitiatus*, the corn sap beetle which is more slender and lighter in color than *C. hempterus*.

SAW-TOOTHED GRAIN BEETLE

The saw-toothed grain beetle, *Oryzaephilus surinamensis* (Linn.), is a cosmopolitan pest that feeds on practically all dried stored food. It infests all cereals (such as

Adult saw-toothed grain beetle, about 9 times natural size (ventral and dorsal views). Note sawlike teeth on edges of the thorax. (Photo by H. Kido.)

rice, wheat, maize, and barley), pastes (such as macaroni), bread, flour, nuts, copra, starch, drugs, tobacco, dried meat, and dried fruit. Raisins are one of its favorite foods.

Appearance. The adult is a very active, slender, flattish, brown beetle, about $\frac{1}{10}$-inch long. It can be recognized by the sharp projections that stand out on each side of the thorax. These somewhat resemble saw teeth and are responsible for the pest's name.

Development. The adult female lays her eggs singly or in small clusters in crevices formed by tight folds in the skin of the raisins. A beetle may lay from one to six eggs a day and about 250 in her lifetime. The eggs are white, shiny, and elongate-oval. Measuring less than $\frac{1}{20}$ inch in length, they are not visible to the unaided eye.

During warm weather the eggs hatch in about 4 days. The larva is pale yellow with a dark band on each segment, and its body is covered with numerous long hairs. The head is yellowish-brown. The larvae crawl actively about, not confining their feeding to a single raisin, but nibbling at random. Fully grown, they measure about $\frac{1}{10}$ inch in length. During warm weather they mature in about 2 weeks.

When ready to transform to the adult, the larva may construct a crude cocoon of tiny particles of trash fastened together with a gluelike material from its mouth. The larva firmly attaches its rear end to some solid object and changes to a pupa. At the end of about 15 days, the adult beetle emerges.

During warm weather the time from egg laying to the emergence of a new adult is about 40 days. There are normally five to six generations each year. With the approach of cold weather the adults hibernate, but indoors in warm buildings they continue to breed and develop throughout the year. Thus, infestation may take place during storage of raisins.

Injury. The saw-toothed grain beetle attacks all parts of the raisin, feeding as much in the deep folds as on the ridges. There is no webbing as is the case with Indian-meal moth or raisin moth damage. The excreta of the saw-toothed grain beetle are yellowish, and the pellets are smaller and more elongate than those of the moth larvae.

Control. Control measures are the same as those used for control of the Indian-meal moth.

LEAD CABLE BORER

The lead cable borer, *Scobicia declivis* (Le Conte), which derives its name from its ability to bore holes in the lead sheathing of telephone cables, also bores holes in wood—a habit which can severely damage wooden wine casks.

Appearance. The adult is a black, cylindrical beetle about ¼-inch long, with a tan or reddish spot on each side of the body near the middle. Both males and females are strong fliers and fly a good deal during warm days.

Development. This pest breeds almost entirely in oak trees, preferring the California live oak and the black oak. Females do not lay eggs in healthy, living oaks or in dead wood invaded by various wood-rot fungi. Instead, they seek out healthy wood that has been cut, felled, or broken off by the wind, preferably wood that has been severed from the tree for a period of 2 weeks to 6 months.

To lay her eggs the female bores through the bark of the oak to the wood, then turns and burrows through the wood parallel to the bark and at right angles to the grain. Eggs are inserted into natural wood pores which are crossed by the tunnel made by the adult. In about 20 days the eggs hatch into white C-shaped grubs that bore through the wood. This stage lasts about 9 months. The grubs then construct a hollow cell in the wood in which to pupate. At the end of about 15 days the adult emerges, remaining inside the pupal cell for about a month while it matures, hardens, and turns black. It then bores its way out and flies off in search of new oak wood.

The lead cable borer has only one generation each year. The adults occur from May to September, inclusive, but are most abundant during July and August. Most of the new adults emerge from the grub-infested wood from July 20 to 30 and live for about 30 days thereafter.

Injury. In wineries the adult stage of the lead cable borer is the destructive one; the white, grublike larvae are not found. These beetles are provided with organs of smell which enable the females to locate freshly-cut oak. Presumably this odor resembles alcohol because the beetles are attracted to wine casks and tanks, boring into the wood as though intending to lay eggs there. Brand-new oak barrels that have never held wine are attractive to the beetles and so are redwood tanks that have held wine; new, unused redwood, however, is not.

Because they find wine leaking out in the morning where no hole was noticed the day before, some vinters believe that the beetles enter the winery at night and bore holes in the casks. This is not correct because a female beetle can bore only ½ inch of tunnel in 24 hours.

Control. Control of this pest in wineries should include sanitation in the immediate neighborhod. Since the beetles breed in oak wood that has been cut for 2 to 6 months, no such cordwood should be piled near the winery. If native oaks are growing nearby, any broken limbs on the ground should be burned by May of each year before any adults can emerge.

Some vinters fill their tanks with water and heat it nearly to boiling in the belief that this procedure kills beetles established in the wood. If this is done early in August, any adults that were boring in the staves at the time of treatment would be driven out by the heat, but the tanks would again be susceptible to attack as soon as they had cooled. There are no eggs or grubs in the wood of the tanks to be killed by heat treatment. Heat treating at any other time than July and August would be futile, and it is of doubtful value during these two months.

POMACE FLY

The pomace fly and its development is discussed under the name of vinegar fly on page 45. The reduction of vinegar flies (often called *Drosophila*) should start in the vineyard. Measures that reduce the numbers of this pest in the field

will reduce the number of flies brought to the winery with the fruit. The fruit should be brought to the winery quickly after it is picked, and processing should start without delay as delays provide greater opportunities for the flies to come to the freshly-picked fruit (which is very attractive for egg-laying).

At the winery, control of *Drosophila* consists of placing barriers to the fruit at all possible stages of processing and storage. This may be done with 24- by 24-mesh screens, or by pressurizing important rooms with air drawn in through a filter and forced out of the openings at 7 to 10 miles per hour. Insecticides are useful when applied to screens or as aerosols, but they must be selected and applied with caution.

Wineries should be designed for sanitation as good housekeeping is most important. Routine cleaning should be frequent. All leakage, wine dampness of bungs, etc, must be cleaned quickly. All waste should be removed from the winery area and spread thinly to dry. When this cannot be done, waste piles must be treated with insecticide. Pomace for further processing at another place should be moved away within five days.

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REFERENCES

AliNiazee, M. T., and E. M. Stafford.
1972. Notes on the Biology, Ecology and Damage of *Platynota stultana* on Grapes. Jour. Econ. Ent. **65**(4):1042–4.
1973. Management of Grape Pests in California Vineyards. 1. Cultural and Chemical Control of *Platynota stultana* on Grapes. Jour. Econ. Ent. **66**(1):154–7.

Barnes, Dwight F.
1944. Notes on the Life History and Other Factors Affecting Control of the Grape Leaf Folder. U.S.D.A. Bur. Ent. and Plant Quarantine **E616.**

Basinger, A. J.
1938. The Orange Tortrix. Hilgardia **11**(11):635–69.

Borden, Arthur D., Harold D. Madsen, and Arthur H. Retan.
1952. A Stink Bug, *Euchistus conspersus* Uhler, Destructive to Deciduous Fruits in California. Jour. Econ. Ent. **45**(2):254–7.

Brown, A. W. A.
1968. Insecticidal Resistance Comes of Age. Bulletin of the Entomological Soc. Amer. **14**(1):3–9.

Davidson, W. M., and R. L. Nougaret.
1921. The Grape Phylloxera in California. U.S.D.A. Bul. **903,** 128 pages.

Doutt, R. L., and J. Nakata.
1965. Parasites for Control of Grape Leafhopper. California Agriculture **19**(4):3.

Doutt, R. L., John Nakata, and F. E. Skinner.
1969. Parasites for Control of Grape Leaf Folder. Califorina Agriculture **23**(4):4.

Ebling, Walter.
1959. Subtropical Fruit Pests, Berkeley: Univ. of Calif. Div. of Agr. Sciences. Pp. 321–339.

Flaherty, Don, Curtis Lynn, Fred Jensen, and Don Luvisi.
1966. Spider Mite Problems in Southern San Joaquin Valley Vineyards. U.S.D.A., and University of California and Counties of Fresno, Kern, and Tulare Cooperating. 10 pages.

Flaherty, D. L., C. D. Lynn, F. L. Jensen, and D. A. Luvisi.
1969. Ecology and Integrated Control of Spider Mites in San Joaquin Vineyards. California Agriculture **23**(4):11.

Hewitt, W. B., N. B. Frazier, H. E. Jacob, and J. H. Freitag.
1942. Pierce's Disease of Grapevines. Calif. Agr. Exp. Cir. **353**:1–32.

Jensen, F. L., E. M. Stafford, H. Kido, and D. Flaherty.
1965. Surveying leafhopper populations. California Agriculture **19**(4):7.

Jensen, F. L., D. H. Flaherty, and L. Chiarappa.
1969. Population Densities and Economic Injury Levels of Grape Leafhopper. California Agriculture **23**(4):9–10.

Jepson, R. L.
1962. Pesticide Resistance in Citrus Mite Control. California Agriculture **16**(11):12.

Kido, H., and E. M. Stafford.
1965. Feeding Studies on the Grape Leafhopper. California Agriculture **19**(4):6–7.

Kido, H., E. M. Stafford, and N. F. McCalley.
1971. Orange Tortrix on grapes in Salinas Valley. California Agriculture **25**(7): 10–11.

Lamiman, J. F.
1933. Control of the Grape Leafhopper in California. Univ. of Calif. College of Agric. Ext. Cir. **72,** 20 pages.

Lange, W. H., Jr.
1944. The Western Grape Leaf Ekeletonizer, *Harrisina brillians* in California. California Dept. of Agr. Bul. XXXIII No. **2.** Pp. 98–104.

Lynn, Curtis D.
1969. Omnivorous Leaf Roller. California Agriculture **23**(4):16–17.

Powell, Jerry A.
1964. Biological and Taxonomic Studies on the Tortricine Moths with References to the Species in California. Berkeley: Univ of Calif. Press. Pp. 203–12.

Smith, Leslie M., and Eugene M. Stafford.
1955. Grape Pests in California. Calif. Agr. Exp. Sta. Circ. **445.** 63 pages.

SMITH, LESLIE M., and ROBERT O. SCHUSTER.
1963. The Nature and Extent of *Eriophyes vitis* Injury to *Vitis vinifera* L., Acarologia **5**(4). Pp. 530–9.

STAFFORD, E. M., F. L. JENSEN, and H. KIDO.
1960. Control of the Grape Leaf Folder in California. Jour. Econ. Ent. **53**(4): 531–4.

STAFFORD, E. M., and A. P. YEARINGTON.
1964. Control of *Drosophila* in Vineyards with Insecticidal Dusts. Jour. Econ. Ent. **57**(6):958–60.

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